shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish-yellow.
Cenozoic	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
Mesozoic	Jurassic		J	Blue-green.
Mesozoic	Triassic		Ꞓ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
Paleozoic	Devonian		D	Blue-gray.
Paleozoic	Silurian		S	Blue-purple.
Paleozoic	Ordovician		O	Red-purple.
Paleozoic	Cambrian	Saratogan; Acadian; Georgian	Є	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure

[illegible] level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain.* If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

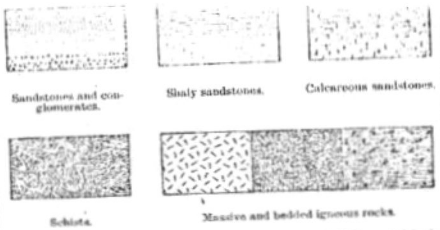

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike.* The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip.*

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines.* But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults.* Two kinds of faults are shown in fig. 4.

the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

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tions. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

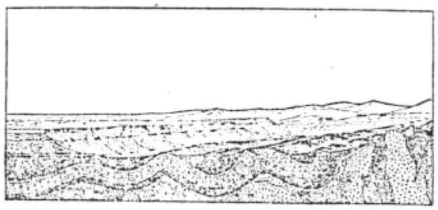

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

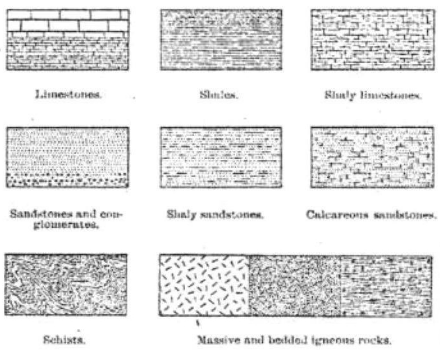

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

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CHARLES D. WALCOTT,

Director.

Revised January, 1904.

Geology and Ore Deposits of the Rico District, Colorado

By EDWIN T. McKNIGHT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 723

A discussion of the geology and potential of a famous old silver camp which, under modern mineral technology, became a lead, zinc, and pyrite camp

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GEOLOGY AND ORE DEPOSITS OF THE RICO DISTRICT, COLORADO

By Edwin T. McKnight

ABSTRACT

The Rico district is in the Dolores River valley at the east end of Dolores County in southwestern Colorado. Mining has been actively carried on in the district since 1879. In the early days, silver was the chief product and was mined largely from Newman Hill southeast of the town of Rico. After 1900, the base metals, particularly lead and zinc, mined in other parts of the district, became the major products, though silver remained an important byproduct. The production of the Rico district from 1879 to 1968 has been about 83,000 ounces gold, 14,500,000 ounces silver, 5,600 tons copper, 84,000 tons lead, and 83,000 tons zinc.

Bedrock in the district ranges in age from Precambrian to Permian. The older rocks are exposed in the valley of the Dolores River and its tributary, Silver Creek, near the center of a domal uplift on the east side of a monzonite stock that crops out west of the river at Rico. Precambrian rocks, which are faulted up in a horst block on the eastern prolongation of the monzonite stock, include an earlier complex of greenstone and metadiorite and the later Uncompahgre Quartzite, which is at least 1,000 feet thick. The Uncompahgre Quartzite is overlain in the subsurface by the Ouray Limestone of Devonian age; this is succeeded by the Leadville Limestone (Mississippian), which is the oldest Paleozoic formation that crops out. Combined thickness of the Ouray and Leadville is about 160 feet. Both formations have been metamorphosed by the monzonite intrusive body.

A quartzite from zero to perhaps 80 feet thick has in previous reports on the district been considered as Devonian in age and then Cambrian. Because of structural and erosional complications near the center of the dome, the sequential relations between this quartzite and the Devonian and Mississippian limestones cannot be determined from outcrops. However, drill-hole records indicate that the quartzite overlies the limestones, and fossiliferous chert pebbles found in this quartzite indicate that it cannot be older than Carboniferous. It is here assigned to basal Middle Pennsylvanian, named the Larsen Quartzite, and is considered to be the equivalent of the Molas Formation in other parts of the San Juan region.

The Hermosa Formation, of Middle Pennsylvanian age, is the most widely distributed formation in the mining district. It is about 2,800 feet thick in its best exposed section, and comprises arkoses, sandstones, shales, conglomerates, and interbedded fossiliferous limestones. Although minor limestone and dolomite are scattered through the formation, most of the limestones are concentrated in the middle third. Conglomerates are concentrated in the upper third, and the proportion of red beds increases toward the top of the formation. Lateral variation in the proportions of the different rock types is extreme, and in the southeastern part of the district, clastic strata largely disappear from the middle part of the section to produce a phase of the middle Hermosa that is thinner but is virtually all limestone. The Hermosa Formation is of great economic interest because most of the ore deposits of the district occur in it, particularly in its limestones.

The Hermosa is overlain conformably by the Rico Formation, about 300 feet thick, of Middle and probably Late Pennsylvanian age. The Rico is dominantly a sandstone and arkose sequence, in part conglomeratic, but contains other lithologic types, including limy fossiliferous sandstones in which pelecypods and gastropods are conspicuous. Many of the strata are red beds, though in general the rocks average little, if any, redder than the upper part of the Hermosa. The Rico is transitional on its lithologic and paleoecologic features between the Hermosa and Cutler Formations.

The highest formation exposed in the district is the Cutler Formation, a continental red-bed sequence of Early Permian age. Perhaps as much as 2,800 feet of strata remain, consisting of arkoses, conglomerates, sandstones, shales, and thin impure fresh-water limestones.

At the end of the Mesozoic Era the sedimentary sequence was intruded by sills and dikes of hornblende latite porphyry, one of the sills being as much as 525 feet thick. Apparently at a later stage, the ensemble was intruded by a less silicic stock of monzonite whose present outcrop, west of the Dolores River at Rico, is about 2 miles long and 1 mile wide. Other igneous types include several dikes of alaskite porphyry and a single thin dike of lamprophyre. Pervasive metamorphism of the sedimentary strata extends for 0.4 mile east from the boundary of the stock, and more channelized metamorphism extends to a maximum distance of 1.7 miles.

The dominant structure of the district is a faulted dome centered near the monzonite stock. The Rico mining district is on the northeast, east, and southeast sides of the dome. In the district the major faults near the stock trend generally east-west and border a central faulted horst block of Precambrian rock that has been uplifted at least 6,000 feet. Farther from the stock are two other major faults of diagonal trend. The Princeton fault strikes northeast through the northern part of the mining district and has its upthrow on the northwest side. The Blackhawk fault cuts from northwest to southeast diagonally across the other faults and has its upthrow on the southwest side, toward the horst block. The major faults that dominate the structural pattern of the district are normal faults, and all except the Princeton fault are of steep dip. In addition, numerous bedding faults in the Hermosa Formation have been of considerable economic importance because they commonly afforded access of ore-bearing solutions to sites favorable for ore deposition.

The ore deposits of the district consist of (1) massive sulfide replacement deposits in the limestones of the Her-

mosa Formation; (2) contact-metamorphic deposits of sulfides and iron oxides in limestones chiefly of the Ouray and Leadville Limestones but also of the Hermosa Formation; (3) veins on fractures and small faults in Hermosa sandstones and arkoses; and (4) replacement deposits in residual debris resulting from the solution of a gypsum bed where broken by fissures in the lower Hermosa Formation.

The common sulfide minerals, present in all types of deposits, are pyrite, sphalerite, galena, and chalcopyrite. A silver-bearing mineral of the tetrahedrite-tennantite isomorphous series is widely distributed. Rarer sulfides, generally confined to certain types of deposits, include pyrrhotite, cosalite, tetradymite, and alabandite. Although no longer of significance as ore minerals, several silver minerals accounted for much of the value in the lodes (types 3 and 4 above) mined in Newman Hill before 1900. These include argentite, polybasite, proustite, pearceite, pyrargyrite, and possibly stephanite and argyrodite. Native gold is generally a minor byproduct, but, locally, it has contributed materially to the value of the ore, particularly in some of the rich silver ore formerly mined in Newman Hill.

The common gangue minerals are quartz, fluorite, calcite, dolomite, manganoan siderite, rhodochrosite, rhodonite, and sericite. Barite is of local occurrence. In the contact-metamorphic ores, specularite, magnetite, and chlorite are major gangues. Many other high-temperature silicates are only incidentally associated with the ores.

The massive sulfide replacement deposits in Hermosa limestone (type 1) have been the major source of ores in the 20th century and account for practically all the current production. They are base-metal ores with byproduct silver and gold. Although found in the neighborhood of certain major faults such as the Blackhawk fault, the individual ore bodies are localized on minor breaks. A given ore body is centered on a fracture or minor fault and commonly involves the complete thickness of the limestone bed. Massive pyrite commonly replaces the ore bed adjacent to the feeding fracture, and sphalerite and galena, with variable, though generally sparse chalcopyrite, ring the periphery of the pyrite body. The pyritic masses yielded the sulfur for a large output of sulfuric acid for 9 years, starting in 1955. Some of the pyrite bodies have carried enough copper locally to have been mined as argentiferous copper ores. These replacement ores have been found chiefly in two areas—in CHC Hill in the northern part of the district, and up Silver Creek, roughly 1½ miles east-northeast of Rico, respectively in the foot wall and hanging wall of the Princeton fault.

The contact-metamorphic deposits (type 2) are likewise base-metal ores with byproduct silver and gold. They are less extensive than type 1, occurring only within or on the borders of the Rico townsite. They were exploited chiefly in the 1920's and again during World War II but are not now productive. The base-metal sulfides occur in irregular pods scattered through masses of specularite, magnetite, and chlorite that are centered on fracture zones of small displacement.

The vein deposits (type 3) are widespread in association with the replacement deposits, but are generally too thin to be economically exploitable for base-metal ores. Locally, they may be worked over short stretches where they widen or are followed by development workings. Veins of a different mineralogic type, characterized by an abundance of rich hypogene silver minerals and appreciable gold in addition to the base-metal sulfides, were worked in Newman Hill in the southern part of the district during the 1880's and 1890's but were largely exhausted by 1900. These veins were in a northeast-trending system and were limited to a stratigraphic interval of about 150 feet, in sandstones and arkoses below a capping shaly zone in the lower Hermosa. The veins averaged only 6 inches thick, rarely reaching a thickness of 2 or 3 feet. They pinched and were impoverished in the shales. In general, vein deposits are on faults of small throw, those in Newman Hill having a displacement of less than 10 feet.

The replacement deposits in residual debris resulting from the solution of a gypsum bed (type 4) were also exhausted before 1900. They were closely related to the rich vein deposits in Newman Hill, occurring in horizontal blanket or ribbonlike deposits overlying the apices of the veins. These so-called "contact" deposits were separated from the veins by a shaly interval, .5–20 feet thick, through which extended only minor irregular stringers of the vein material. The contact deposits were from a few inches to 6 feet thick, as much as 40 feet wide centered over the apex of the related vein, and several hundred feet long following the strike of the vein. They occurred not only over the northeasterly veins, but over northwesterly veins that were barren in the vein zone. Mineralogically, the contact deposits were similar to the productive veins, but the ore averaged considerably richer.

INTRODUCTION

LOCATION AND GEOGRAPHY OF DISTRICT

The Rico district is near the east end of Dolores County, Colo. (fig. 1), in the Rico Mountains, a subsidiary group of peaks on the southwest fringe of the San Juan Mountains. Although the peaks are high relative to the plateau country on the west and southwest, they are low relative to the San Juan Mountains. The highest point is Blackhawk Peak, at 12,677 feet, 2½ miles east of the town of Rico. Other peaks that more closely overlook the town, all more than 12,000 feet in altitude, are Dolores Mountain to the southeast, Telescope Mountain to the northeast, and Expectation Mountain across the river to the west. The headwaters of the Dolores River flow south through the heart of the district, and Rico is on its east bank at the confluence of Silver Creek. This creek comes from the northeast between Telescope Mountain and high spurs, including Harts Peak, that extend out from Blackhawk Peak.

The lower slopes of the Rico district are generally mantled by wash, talus, and landslide debris that has slid down from the higher hills. Alluvial fans are extensive at the mouths of the larger creeks. The general effect has been to limit the rock outcrops at lower levels, including much of the mineralized area. The outstanding exception is Sandstone Mountain, on the west side of the river, 2 miles north of Rico. Here, an extensive landslide off the west slope of Telescope Mountain has pushed the Dolores River against its west bank, so oversteepening the slope

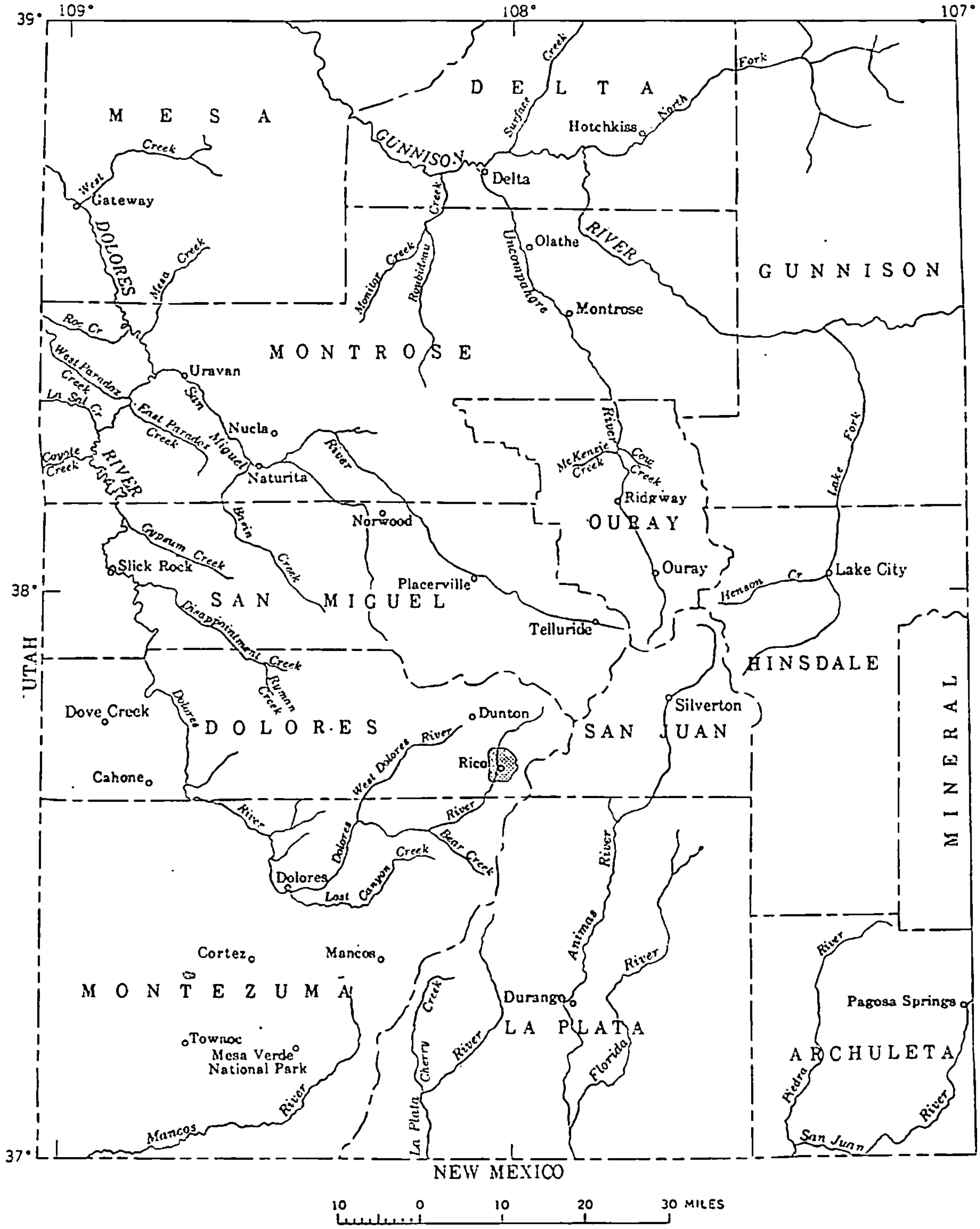

FIGURE 1.—Index map of southwestern Colorado showing location of the Rico district.

that most talus debris on that side has gone into the river and has been distributed in the alluvial material along the valley below. The resultant outcrop face on Sandstone Mountain exposes a stratigraphic section that has been of utmost importance in deciphering the geology of the district. Elsewhere in the district, indifferent outcrops yield only partial sections that can be interpreted only by reference to the Sandstone Mountain section or to underground exposures.

The hills have a discontinuous forest cover in which aspen, Colorado blue spruce, and Englemann spruce at higher levels are dominant types. The timberline is at about 11,500 feet.

Although some mineralized ground is on the west side of the river opposite Rico, the major production from the district has come from mines east of the river. Some of these mines have been in blocks of ground mantled by thick wash and landslide debris. Because of their importance as mining areas, some of these mantled lower slopes of the mountains have been given special names. Thus, CHC Hill is the lower west slope of Telescope Mountain, and Newman Hill is the lower west slope of Dolores Mountain. The major mineral production has come from CHC Hill; from Nigger Baby Hill, which is the long spur that extends southwest from Telescope Mountain and overlooks Rico; from the valley of Silver Creek about 1½ miles northeast of Rico; and from Newman Hill.

In the early production of the district, silver was the major economic product; but upon depletion of the rich silver ores, lead, zinc, and, to a less extent, copper have been the main products, and silver has been an important byproduct. Gold has always been a significant byproduct, and at least one small mine has been worked exclusively for this metal. In 1955 a plant was built for production of sulfuric acid from massive pyrite ores, and in the next 9 years a substantial amount of acid was produced for use in uranium mills of the adjacent Colorado Plateau.

HISTORY

The early history of the Rico mining district has been given by Ransome (1901, p. 238–242) and therefore is only summarized here. The first claim was staked in 1869 on ground along the river at Rico, including parts of what later became the Shamrock, Smuggler, and Riverside claims. In the next 10 years, additional claims were staked within the Rico town area, on Nigger Baby Hill, in the mineralized area up Silver Creek, and in Aztec Gulch. Development work was intermittent, however, and the claims were commonly abandoned on the approach of winter.

In 1879, oxidized silver ores were discovered on Nigger Baby Hill which were rich enough to attract a sharp influx of prospectors into the district. A mining settlement sprang up, civil government was organized, and a post office was established at Rico. In the same year, ore was discovered and shipped from one of the veins in Newman Hill. General activity in the camp increased over the next few years. In 1880 a small smelter was built on the east bank of the Dolores River at the north edge of town to treat the ores from the Grandview mine, but it proved to be short lived. A second smelter was built at the southern end of town, beginning in 1882, and operated as a custom plant for nearly 2 years during 1884–86. Silver production rose to a temporary peak of 193,360 ounces in 1883, but it sagged appreciably in the next 3 years.

In 1887 a prospect shaft on the Enterprise claim, by pure accident, struck the edge of the largest and richest ore body ever found on Newman Hill. This was a blanket ore body of a type that proved to be very productive of rich silver ore during the next few years, as further ore bodies were explored and opened in the extension of mining from this initial discovery. The Enterprise success stimulated development throughout the camp, and within the next few years ore had been developed in all the mineralized areas that are now known, including CHC Hill. The Rio Grande Southern Railroad Co. completed a narrow-gage line into the camp in 1890, and within a short time spur lines were operating up Silver Creek and to the portal of the Enterprise Group tunnel.

The all-time peak of silver production was reached in 1893, 2,675,238 ounces, of which the mines in Newman Hill, particularly the Enterprise mine, contributed the largest share. The drop in silver prices during the 1890's, and particularly the famous silver panic in mid-1893, affected Rico as it did all other western mining camps, and the production fell sharply in the next few years. Yet the fundamental cause for the decline as a silver camp was depletion of the rich silver ores. By the time of the Ransome (1901) report, the Newman Hill mines were largely exhausted of all except low-grade base-metal ores.

In the early 1900's, other parts of the district became relatively more productive, and by 1905 for the first time the combined values of lead and zinc produced in the district exceeded that of silver. Activity in the district waxed and waned with the economics of mining during the next several years, but there was substantial development and production each year. The demands for base metals before and during World War I stimulated the mining of base-metal ores, particularly in CHC Hill and in the mineralized area up Silver Creek. However, peaks of production generally depended on the fortunes of ore discovery. A temporary peak for base metals was reached in 1913 when the district produced 400 tons of copper, 1,540 tons of lead, and 1,300 tons of zinc. Although the output of lead and zinc fluctuated at a lower level in the next few years, the all-time peak production of copper, 516 tons, was reached 2 years later, principally from the Mountain Spring-Wellington mine of the Rico-Wellington Mining Co.

in CHC Hill. Mining economic conditions began to deteriorate during the last year of the war, and production reached a low ebb by 1921.

In the mid-1920's the mining industry at Rico revived, chiefly through advances in the metallurgical industry. Perfection of the flotation process in the previous decade had made attractive such complex sulfide ores as prevail at Rico, and the mine operators were, for the first time, able to realize a fair profit on the zinc content of their ores instead of being penalized for it as in past years. At first, the ores were shipped to new custom flotation mills in the Salt Lake area, Utah, but in 1926 a 250-ton custom mill was built at Rico by the International Smelting Co. (subsidiary of Anaconda Mining Co.), and for nearly 2 years most of the output of the district was concentrated in this mill. The chief producing companies included the Rico Argentine Mining Co., working the mineralized area up Silver Creek on the south side of the creek; the Falcon Lead Co., working the Yellow Jacket mine and other properties on Nigger Baby Hill; the Rico Mining & Reduction Co. and (after May 1927) its successor, the St. Louis Smelting & Refining Co., working CHC Hill, the Silver Swan mine below Rico, and a small part of the mineralized area along Silver Creek; the Pelleyre Mining & Milling Co. (subsidiary of International Smelting Co.), working the Shamrock and several other properties in the district; Union Carbonate Mines, Inc., working the Union Carbonate mine; and the Rico Enterprise Mining Co., working the Pro Patria and Revenue mines. The all-time peak of production for base metals was made in 1927 when the district output was 5,308 tons of zinc, 4,994 tons of lead, and 65 tons of copper. The mining boom was, however, relatively short lived. The custom mill at Rico operated only from October 1926 to July 1928, when it shut down permanently. Ore that continued to be produced for a time was shipped again to the custom mills at Salt Lake.

In 1929 mining at Rico was hit by the Depression, and by 1932, production had ceased. The St. Louis Smelting & Refining Co. drove its St. Louis tunnel and crosscut extensions into the east bank of the Dolores River under CHC Hill during the depth of the Depression (1930–32), but failed to reach the Mississippian and Devonian limestones in which deep replacement ores were prospective targets. Mining was resumed on a relatively small scale in 1934, and production from several mines fluctuated over the next few years.

In September 1939, the Rico Argentine Mining Co. finished a new 135-ton flotation mill and began a period of steady production that brought a degree of stability to the mining industry at Rico. This company was the major producer during World War II. The Van Winkle shaft was sunk on the east edge of town in 1942, and for several years supplied a large share of the Rico Argentine production. The company has maintained steady production, though not always at mill capacity, to the present day except for two periods, May 1949 to July 1950, and June 1957 to some time in 1959, when low base-metal prices made the operation uneconomic. The long crosscut from the St. Louis tunnel to the Argentine shaft on Silver Creek was finished in 1955, lowering the water level in the Silver Creek mine workings by about 450 feet and draining a large block of mineralized ground. At present, the company controls most of the mining properties from which the major past production of the district has come. Its mill capacity (1969) is rated at 150 tons per day.

In September 1955, the Rico Argentine Mining Co. completed and put in operation a plant for the production of sulfuric acid from pyrite. The acid was sold to several uranium mills operating in the adjacent part of the Colorado Plateau. The acid plant ran for 9 years, until a cutback in the uranium program destroyed the market for the acid. The plant was put on a standby basis in October 1964. Much of the acid production came at a period of low base-metal prices, when the entire mining facilities could readily be diverted to the mining of pyrite.

TRANSPORTATION FACILITIES

The narrow-gage railroad completed through Rico by the Rio Grande Southern Railroad Company in 1890 served the district for 60 years. In its later days, locomotive power was supplied by various models of converted automobile gasoline engines. Eventually, freight from the mining industry at Rico and Telluride was not enough to sustain the railroad, and it was finally abandoned as uneconomic in 1951. Since then, mining supplies have been brought in and concentrates taken out by truck. At present (1969), all concentrates are trucked to the Denver and Rio Grande Western Railroad line at Ridgway, Colo., where they are loaded into freight cars and shipped to the Bunker Hill Co. reduction plants at Kellogg, Idaho.

PRODUCTION

Table 1 gives the production of precious and base metals from the Rico district from 1879–1968.

Between September 1955 and October 1964, the acid plant produced 316,108 tons of commercial sulfuric acid, 100 percent basis. In the first year and a quarter, pyritic tailings from the lead-zinc mill

TABLE 1.—*Gold, silver, copper, lead, and zinc produced in the Rico district, 1879–1968*

[Figures derived by subtracting from the production of Dolores County that of the Lone Cone district, which is the only other metal-producing district of record (1896–1941) in the county. Lone Cone production for 1896–1903 estimated (gold and silver only), for later years from unpublished statistical charts furnished by the U.S. Bur. Mines. Production of Dolores County for 1879–1923 from Henderson (1926, p. 117); for 1924–31, from annual volumes of U.S. Bur. Mines Mineral Resources of the United States; for 1932–62, from annual volumes of U.S. Bur. Mines Minerals Yearbook; for 1963–68, from unpublished statistics furnished by U.S. Bur. Mines. Compilation for Dolores County by Robert G. Luedke, U.S. Geol. Survey]

Year	Lode gold		Silver		Copper		Lead		Zinc		Total value
	Fine ounces	Value	Fine ounces	Value	Short tons	Value	Short tons	Value	Short tons	Value	
1879	73	$1,500	7,734	$8,662	2	$800	5	$410	----	----	$11,372
1880	169	3,500	30,938	35,579	14	6,206	50	5,000	----	----	50,285
1881	242	5,000	69,510	78,659	22	8,008	100	9,600	----	----	101,267
1882	484	10,000	85,078	96,989	27	10,314	100	9,800	----	----	127,103
1883	242	5,000	193,360	214,630	60	16,500	100	8,600	----	----	244,730
1884	73	1,500	54,141	60,097	--	----	75	5,624	----	----	67,221
1885	193	4,000	70,000	74,900	--	----	50	3,900	----	----	82,800
1886	414	8,561	75,836	75,078	--	----	396	36,432	----	----	120,071
1887	471	9,743	118,262	115,897	17	4,692	500	45,000	----	----	175,332
1888	845	17,470	123,852	116,421	--	----	500	44,000	----	----	177,891
1889	3,765	77,825	618,615	581,498	--	----	1,000	78,000	----	----	737,323
1890	7,561	156,297	848,785	891,224	--	----	1,000	90,000	----	----	1,137,521
1891	5,932	122,631	699,888	602,889	--	----	466	40,047	----	----	855,567
1892	11,401	235,669	1,285,179	1,118,106	7	1,513	1,542	123,327	----	----	1,478,615
1893	21,387	442,105	2,675,238	2,086,686	5	1,080	2,250	166,500	----	----	2,696,371
1894	9,318	192,626	1,153,325	726,595	15	2,850	1,000	66,000	----	----	988,071
1895	2,542	52,562	399,283	259,534	32	6,864	157	10,042	----	----	328,002
1896	216	4,465	221,393	150,547	--	----	550	33,000	15	$1,170	189,182
1897	603	12,464	104,901	62,941	20	4,758	547	39,378	----	----	119,541
1898	1,771	36,607	338,346	199,524	75	18,556	343	26,091	200	18,400	299,278
1899	1,234	25,508	157,052	94,231	22	7,611	1,023	92,080	50	5,800	225,230
1900	925	19,120	84,318	52,227	18	5,978	105	9,257	110	9,650	96,262
1901	179	8,700	66,632	39,979	7	2,189	184	15,783	125	10,250	71,901
1902	296	6,118	46,311	24,545	8	1,837	194	15,941	124	11,937	60,378
1903	293	6,056	45,096	24,352	74	20,220	72	6,024	----	----	56,652
1904	657	13,578	44,432	26,251	13	3,250	91	7,793	9	928	51,800
1905	206	4,250	29,496	18,275	60	18,592	420	39,495	278	32,820	113,532
1906	455	9,398	34,290	23,317	100	38,480	59	6,739	442	53,896	131,830
1907	132	2,734	20,317	13,409	50	19,899	27	2,891	----	----	38,933
1908	588	12,155	85,310	45,214	21	5,488	474	39,772	255	23,932	126,561
1909	514	10,641	64,375	33,475	22	5,521	230	10,756	84	9,049	78,542
1910	320	6,616	49,795	26,889	48	12,113	62	5,479	44	4,698	55,795
1911	23	475	30,842	16,346	2	373	350	31,476	263	29,944	78,614
1912	64	1,313	68,794	42,309	345	113,709	604	54,339	406	56,030	267,700
1913	306	6,333	153,111	92,479	400	124,057	1,538	135,332	1,298	145,389	503,590
1914	317	6,542	80,844	44,707	175	46,576	246	19,166	183	18,694	135,675
1915	524	10,828	122,664	62,190	516	180,670	134	12,593	18	4,456	270,737
1916	269	5,557	71,573	47,098	210	103,197	294	40,561	91	24,429	220,832
1917	252	5,213	88,222	72,695	260	141,937	886	152,411	851	173,538	545,704
1918	145	2,991	54,240	54,240	309	152,649	259	36,735	331	60,174	306,789
1919	122	2,517	35,084	39,294	132	49,284	49	5,231	34	4,893	101,219
1920	85	1,759	28,556	31,128	3	1,252	336	61,752	115	18,619	114,508
1921	68	1,401	10,524	10,524	1	96	9	838	----	----	12,859
1922	54	1,126	25,423	25,423	12	3,252	44	4,706	----	----	34,507
1923	56	1,154	33,471	27,447	28	8,336	81	11,331	69	9,384	57,652
1924	8	178	8,709	5,835	6	1,545	89	14,167	11	1,417	23,142
1925	83	1,722	37,994	26,368	23	6,674	908	157,075	1,053	160,056	352,795
1926	189	3,902	92,040	67,433	54	15,036	2,917	466,760	2,981	447,150	990,281
1927	411	8,488	173,395	93,315	65	17,161	4,994	629,230	5,308	679,360	1,432,554
1928	1,044	21,585	350,653	205,132	444	127,730	4,626	524,964	4,646	566,812	1,446,223
1929	532	11,016	268,783	143,261	164	57,596	3,530	444,739	2,952	389,730	1,046,342
1930	386	7,975	80,683	31,063	155	40,170	678	67,750	595	57,120	204,078
1931	34	697	1,648	478	1	182	35	2,553	41	3,116	7,026
1932	5	95	2	1	--	----	----	----	----	----	96
1933	40	817	4,820	1,687	1	51	3	222	----	----	2,777
1934	352	12,287	49,302	31,872	10	1,584	119	8,843	107	9,202	63,788
1935	656	22,944	71,040	51,060	13	2,075	140	11,220	142	12,452	99,751
1936	309	10,801	20,031	15,514	7	1,288	119	10,948	139	13,950	52,501
1937	188	6,566	13,086	10,122	7	1,694	125	14,607	136	17,680	50,759
1938	34	1,200	4,642	3,001	2	333	29	2,622	30	2,880	10,036
1939	121	4,235	41,356	28,072	65	13,416	752	70,688	867	90,168	206,579
1940	275	9,625	163,990	109,504	482	109,045	1,028	192,750	2,607	328,482	749,406
1941	102	3,570	112,715	80,153	62	14,632	2,525	287,833	3,004	450,600	836,788
1942	119	4,165	110,918	78,876	35	8,482	2,282	306,795	2,764	514,178	911,495
1943	127	4,445	145,021	103,126	72	18,785	2,566	384,900	3,662	788,832	1,300,088
1944	141	4,935	121,791	86,607	118	31,095	2,826	452,240	4,557	1,038,996	1,614,733
1945	157	5,495	152,266	108,278	86	23,220	2,440	419,680	3,920	901,600	1,458,273
1946	136	4,760	173,297	140,024	112	36,126	2,176	474,259	3,435	838,140	1,493,309
1947	104	3,640	124,199	112,400	109	45,591	2,042	588,168	3,433	830,883	1,580,682
1948	108	3,780	132,312	119,749	74	32,116	2,430	869,940	3,180	845,880	1,871,465
1949	79	2,765	80,032	72,433	33	13,002	1,388	438,608	1,354	335,792	862,600
1950	71	2,485	72,735	65,829	35	14,560	1,138	307,260	1,365	387,660	777,794
1951	220	7,700	131,912	119,387	51	24,684	2,231	771,926	2,527	919,828	1,843,525
1952	128	4,480	127,446	115,345	73	35,332	2,230	718,060	2,734	907,688	1,780,905
1953	95	3,325	103,908	94,042	18	10,332	1,871	490,202	2,634	605,820	1,203,721
1954	147	5,145	118,621	107,358	11	6,490	2,177	596,498	2,896	625,536	1,341,027
1955	156	5,460	114,392	103,531	5	3,730	2,202	656,196	2,571	632,466	1,401,383
1956	179	6,265	97,181	87,954	6	5,270	1,858	583,396	1,668	457,114	1,139,999
1957	13	455	8,829	7,991	1	181	201	57,515	159	36,958	103,100
1958	----	----	----	----	--	----	----	----	----	----	----
1959	18	630	17,562	15,894	3	1,760	325	74,865	362	83,214	176,353
1960	84	2,940	81,593	73,846	10	6,388	1,377	322,183	961	248,041	653,398
1961	63	2,205	49,001	45,384	7	4,290	833	171,444	947	217,695	441,018
1962	46	1,610	31,523	34,202	5	2,895	782	143,952	681	156,722	339,381
1963	25	875	30,112	38,517	5	3,326	542	117,050	484	111,320	271,088
1964	22	770	21,939	28,367	3	2,184	484	126,677	408	135,443	293,441
1965	68	2,380	74,129	95,840	18	12,850	1,457	454,521	1,456	425,137	990,737
1966	68	2,380	54,533	70,511	26	18,664	1,109	335,220	1,147	332,674	759,449
1967	57	1,995	71,397	110,650	20	15,176	1,449	405,804	1,708	472,849	1,006,474
1968	59	2,316	77,129	165,411	18	15,023	1,461	386,028	1,610	434,808	1,003,586
Total	83,045	1,781,702	14,513,288	11,735,029	5,637	1,951,561	83,847	15,228,650	82,717	17,243,559	47,940,501

altitude 9,742 feet and bears generally east-southeast, nearly parallel to the strikes of the Blackhawk fault and of the strata. Its portal is 25 feet within the hanging wall of the Blackhawk fault just southeast of the Last Chance fault junction, and the entry tunnel merges onto the fault 250 feet from the portal. The mineralized ground is in the hanging wall to the northeast. At 340 feet from the portal, the main tunnel crosscuts over to the northeast to follow the Alleghany fissure, which is parallel to and about 200 feet from the Blackhawk fault; but farther along the tunnel, a branch crosscuts back to the Blackhawk fault and drifts along a small break in its immediate hanging wall (pl. 3*A*). Maximum penetration of the Log Cabin tunnel is about 1,400 feet into the hill.

The limestone beds mineralized include the H, I–J, K, and L beds at the top of the middle Hermosa. The distribution of the beds at the Log Cabin level is shown on plate 3*A*. Most of the stopes at and above the Log Cabin level are between the Alleghany and Blackhawk breaks and within 210 feet of the latter, but those on the H and I–J beds follow eastward diagonally down the bedding to the Argentine level. As the Blackhawk fault also dips in this direction, though at a steeper angle, the distance between the fault and the outer edges of mineralized ground does not greatly increase. In a part of the ground, the stopes in the four ore beds are roughly superposed, indicating a common feeder system among the cross fractures. No single fracture can be mapped to account for this, but a system of connecting fissures are present. The ore solutions were thus able to travel from one to the other in a general zone of fracturing. The stope in the H bed, extending from below the Argentine level at the bottom to above the Log Cabin level at the top, is 420 feet long and a maximum of 60 feet wide, as projected on a horizontal plane. The stope in the I–J bed bottoms at the Argentine level and extends up through the Log Cabin level to somewhat above the Carbonate tunnel whose caved portal is 109 feet above the Log Cabin portal. This stope (as projected) is 580 feet long and a maximum of 150 feet wide, though averaging 60–80 feet. The stope in the K bed, which is thin, bottoms between the Argentine and Log Cabin levels and extends through the Log Cabin level to some distance above the Smith tunnel, breaking through to the surface at its upper end. It has a projected length of 500 feet and a width that is generally less than 40 feet, but attains 90 feet at the upper end. A persistent bedding fault at the top of the K bed may have furnished the structural setting for the mineralization. In the L bed, part of the stoping is superposed on that in the lower beds, but there is extensive stoping which is independent of that in lower beds. None of the stopes in the L bed extend below the Log Cabin level. The largest stope, superposed at the west end and running more nearly parallel to the strike of the bedding, is 580 feet long and maximum 120 feet wide.

The Alleghany fissure, so conspicuous on the map of the Log Cabin level (pl. 3*A*), may have been a mineralizing fissure for all the traversed beds (H to L) adjacent to its northwest extent along the level, but it failed to mineralize the L bed for a long stretch near the southeast end of the level. The fissure is a fault of reverse throw and small displacement. It dips mostly southwest at 60°–80°, with the southwest side up 5–18 feet as measured on the level. The fissure contains 2–8 inches of gouge, pyrite, calcite, and, locally, some sphalerite.

BLACKSMITH TUNNEL

Although the Blacksmith tunnel has not been accessible during the fieldwork for the present report, it is of special interest because of the stratigraphic units involved in the mineralization. The tunnel portal is S. 56° E., 530 feet from the Log Cabin portal, and about 267 feet higher. As interpreted from cross section and stope maps prepared by W. R. Landwehr, geologist of the American Smelting & Refining Co., the tunnel provided access to stopes in the two lowest limestone beds of the upper Hermosa within 200 feet of the Blackhawk fault. The stratigraphic units mineralized are Nos. 27 and 29 of the composite section (see p. 24), whose bases are about 126 and 202 feet, respectively, above the base of the upper Hermosa. The lower stope trends nearly parallel to the strike of the bedding and is 185 feet long and 40 feet wide maximum. The upper one, which is really two closely juxtaposed stopes of very irregular outline, shows an overall projected length of nearly 200 feet down the dip of the bedding starting from the Blackhawk fault and a maximum width of 120 feet. These stopes are not superposed, nor do they overlie stopes in limestones of the middle Hermosa. Lower limestone strata at the top of the middle Hermosa are pinched out against the fault below the level of the Blacksmith tunnel.

ARGENTINE TUNNEL

The Argentine tunnel is in the hanging-wall block of the Blackhawk fault northeast of the Log Cabin tunnel and about 160 feet lower, its portal having an altitude of about 9,588 feet. It trends in a general southeasterly direction nearly parallel to the strike of the bedding and shows an overall penetration of about 2,400 feet into the hill. In the first 930 feet are several prongs that are more or less interconnecting, but beyond that, the working is a linear tunnel from which a few crosscuts have been extended (pl. 3*B*).

Some of the prongs of the tunnel in the first 930 feet intersect the lower ends of two of the large stopes previously discussed for the Log Cabin level, namely, those in the H and I–J beds. At their lower ends the outer edges of these stopes are, respectively, 160 and 220 feet from the Blackhawk fault, as measured on the level. Much of the ore from stoping in the K bed between the Argentine and Log Cabin levels was also taken out through these prongs of the tunnel. The Argentine workings in this block also intersect mineralized ground in a lower bed, the E bed, which pinches out against the Blackhawk fault well below the Log Cabin level. The stoped ground in the E bed is small and is characterized by an abundance of garnet. Plate 3*B* shows the distribution of the limestone beds on the Argentine level.

The Blackhawk fault has been probed by crosscuts at four places (pl. 3*B*), but no workings penetrate more than 40 feet into the lower Hermosa strata of the footwall.

The other dominant structure revealed on the tunnel level is the Honduras fault, which is a reverse fault trending slightly south of east and dropping the strata on the north side about 140 feet. Although the displacement is in the same direction as that of the Blackhawk fault, the dip is in the opposite direction, mostly 70°–80° S. The fault break is occupied by 2–8 feet but commonly about 5 feet of gouge, quartz, and pyrite. The I–J bed limestone unit in the dropped block has been mineralized and stoped at a level between the Argentine and underlying Blaine level. This "4 bed" stope,[7] though irregular in shape, is about 250 feet long in a direction nearly perpendicular to the fault and 90 feet wide at the maximum. However, another prong of the stope 10–20 feet wide follows along the north side of the fault for a distance of 140 feet west from the main stope. Mineralization of this latter prong can be attributed to shattering along the hanging-wall side of the Honduras fault. The main northward-trending prong lies along the northwest side of the Rico Argentine dike; shattering of the limestone adjacent to the dike probably furnished the channelways for introduction of the ore solutions. However, the northern part of the stope is also traversed by a small fault dipping westward at 45°–60° and dropping the strata on the west about 15 feet. Updip and a little farther north this fault was responsible for a replacement blanket of sulfide ore at a higher stratigraphic level in the middle tunnel of the Rico Consolidated mine (see p. 84). The remote end of the "4 bed" stope is about 450 feet from the Blackhawk fault. The stope is of mineralogic interest in that cosalite and huebnerite, rare minerals for the district, are present in the massive pyritic replacement ore.

In the ground explored by the deeper parts of the Argentine tunnel, mineralization was not so extensive as in the first 930 feet. The deeper part of the tunnel follows the general course of the Alleghany fissure. Over much of the Argentine level this fissure is 60–120 feet northeast of the Blackhawk fault, striking nearly parallel to it but dipping generally in the opposite direction (southwest) at 60°–80°, except near the southeast end of the mine where it steepens through verticality and farther southeast dips parallel to the Blackhawk fault. Displacement on this level amounts to a few tens of feet, down on the northeast. Although the northwest end of the Alleghany fissure was apparently an important part of the feeder system for the mineralization in the front part of the mine, it was a less effective mineralizer farther southeast. Nevertheless, there are some stopes that are obviously related to it. Where it intersects the I–J bed above the Argentine level in the 3-compartment raise to the Log Cabin level, at 14,060N, 14,690E (pl. 3*B*), a stope extends southeast for at least 180 feet. The stope is about 10 feet wide, and narrowly confined to the intersection of the fissure with the ore bed which here strikes nearly parallel to the fissure and dips about 45° NE. This stope is about 150 feet from the Blackhawk fault.

At 250 feet from the southeast end of the tunnel where the Alleghany fissure dips northeast, its hanging wall contains the 138 stope which is a pyritic copper stope in the L bed, running eastward diagonally down the dip of the bedding to the Blaine level. Owing to the gradual convergence of the Alleghany fissure and Blackhawk fault at this end of the mine, the 138 stope is also only a short distance in the hanging wall of the Blackhawk fault, 60 feet from the fault at the Argentine level and 120 feet from the fault at the Blaine level. The stope is 300 feet long as projected on a horizontal plane and a maximum of 70 feet wide. Slickensides in the stope indicate that faulting along the bedding was an important structural preliminary to the mineralization. The stope is reported to have yielded 2 ounces of silver for each percent of copper.

[7] The stope is labeled "4 bed" stope on mining company maps, but this is a misidentification, as it is really in the 2 bed of company terminology: see the composite section, p. 24.

A crosscut to the northeast near the end of the Argentine tunnel intersects a bedding fault near and at the top of the L bed. There has been some stoping of this bed on and below the fault and updip from the level, but the amount of ore obtained was not great. The mineralized segment of the ore bed is bounded laterally by crosscutting porphyry dikes, one of which was offset by the bedding fault. Stoped ground in this block is a maximum of 250 feet from the Blackhawk fault.

RICO CONSOLIDATED TUNNELS

The three tunnels of the Rico Consolidated mine are about 400 feet northeast of the Argentine portal. The altitude of the upper tunnel portal is 9,629 feet, and of the middle portal, about 9,563 feet. Both portals are caved; but the middle tunnel is accessible from the Argentine workings, and the upper tunnel is accessible from the middle tunnel. The lower tunnel is caved.

The tunnels enter the hill in an irregular, but generally, south-southeasterly direction. The middle tunnel at about 600 feet from the portal hits the Honduras fault and drifts east on it for 250 feet (pl. 3*B*). The strata traversed are chiefly the basal part of the upper Hermosa. However, the L bed, at the top of the middle Hermosa, is intersected 80 feet before the Honduras fault is reached and is also cut on the south side of the Honduras fault in the drift to the east. It is not mineralized.

The only mineralized ground is in the front part of the mine, in the lowest good limestone bed of the upper Hermosa, unit 27 of the composite section (see p. 24). Most of the mineralization is adjacent to the 210 Drift fault near its northeast end, and chiefly on its south or upthrown side. In contrast to its general vertical attitude elsewhere, the fault here dips 70° S., and hence shows reverse displacement amounting to about 20 feet. A large stope 20–30 feet wide plunges eastward diagonally down the dip of the bed at its intersection with the fault, and a pyritized blanket of the ore bed about 100 feet wide extends south from the fault diagonally up the bedding dip and nearly perpendicular to the fault. This pyrite blanket is traversed lengthwise by the small cross fault, dipping 46°–60° W., that is followed for several hundred feet by the main tunnel. The fault drops the strata on the west about 17 feet and also displaces the Rico Argentine dike (pl. 3*B*). It is undoubtedly the feeder for the sulfide mineralization in the pyritic blanket. The center of this blanket is too low grade to be minable, but ore stopes were developed along its two sides. The larger stope on the east side is about 160 feet long as projected on a horizontal plane and is 15–20 feet wide. A bedding fault at the top of the ore bed doubtless facilitated the introduction of the ore solutions. The presence of hydrated iron oxides and green copper stains in the walls of the stopes suggests that the ore taken out was partly oxidized.

An additional small stope was opened along the northwest side of the Rico Argentine porphyry dike. This stope was not completely mapped, so its length is not available. It has a maximum width of 20 feet but is for the most part only 6 or 7 feet wide.

The upper tunnel explores the ore bed at a higher level where it is massively pyritized, but there was only negligible stoping on this level, along the edge of the porphyry dike. The tunnel crosses the vertical Honduras fault at 590 feet from its portal and extends 155 feet farther into the footwall.

The stopes on the middle tunnel level are 600–800 feet from the Blackhawk fault and 260–460 feet from the Honduras fault. It appears obvious that the 210 Drift fault, which in most places is a tight poorly mineralized fissure, has acted as a mineralizing channel in this place, though the eventual trunk channel may well have been the Blackhawk fault.

JAMES G. BLAINE TUNNEL

The Blaine tunnel enters the southeast bank of Silver Creek just above creek level at an altitude of about 9,336 feet, 400 feet east of the Rico Argentine mill. It starts on the southwest side of the Blackhawk fault in the thick shale unit just above the H bed of the middle Hermosa and follows a general east-southeast course until it intersects the Blackhawk fault, 410 feet from the portal. From here, the course is southeast along the Blackhawk fault, though the fault is not followed in detail (pl. 3*C*). In the first 1,700 feet from the portal there is, in addition to the main haulage tunnel, an intricate system of drifts, crosscuts, and stopes that develop the blocks of ground on both sides of the fault, but particularly the northeast, or hanging-wall, side. Beyond 1,700 feet from the portal (measured in a straight line), the chief working is the main haulage tunnel, but numerous tributary crosscuts explore adjacent ground. The total straight-line length of the tunnel is 3,750 feet, though the actual length is somewhat greater because of deviations in course. In the last 1,250 feet, the main tunnel diverges from the Blackhawk fault into its hanging wall, though crosscuts to the fault indicate that the tunnel is nowhere more than 125 feet northeast from the fault.

The structure in the front 1,700 feet of the Blaine workings is greatly complicated by the junction of the Honduras and Blackhawk faults on this level. Although both faults drop the strata on the north

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GEOLOGY OF THE RICO MOUNTAINS, COLORADO

BY

WHITMAN CROSS and ARTHUR COE SPENCER

GEOLOGY OF THE RICO MOUNTAINS, COLORADO.

By Whitman Cross and Arthur Coe Spencer.

PREFACE.

By Whitman Cross.

The Rico Mountains, the area discussed in the accompanying report, are situated in southwestern Colorado near the headwaters of the Dolores River. The summits of this compact and rather isolated group lie within an oval area about 7 miles in diameter from east to west and 5 miles from north to south. Some 8 miles to the northeast is the southwestern front of the San Juan Mountains, and about 16 miles to the south rise the northern slopes of the La Plata Mountains. The peaks are nearly all included within the northeastern section of the Rico quadrangle, but a few lie to the east of the one hundred and eighth meridian, in the Engineer Mountain quadrangle.

The name "Rico Mountains" was first applied to this group of peaks in the course of the work leading to the present report. On the Hayden map of Colorado the term "Bear River Mountains" was used for the same group, but that name has never come into local use, and would now be a misnomer, for it is connected with a nomenclature for important streams which has also failed of acceptance in the settlement of the country since the issue of the Hayden map. On that map the stream now known as the "West Dolores" River was called "North Fork of Rio Dolores;" the main stream, now named the "Dolores River," was designated the "South Fork of Rio Dolores, or Bear River," and from the latter alternative name originated the term applied to the mountains in question. The tributary of the Dolores heading in the La Plata Mountains has long been known as Bear Creek. On the Hayden map it has the name "La Plata Fork."

While the Hayden name for this mountain group has been rejected in local usage the engineers and miners of the region have failed to supply a new one, but the individual character of the group, both geologically and physiographically, makes some name desirable, and that here adopted seems most appropriate. The mining town of Rico is situated in the Dolores Valley, in the heart of the group.

A detailed survey of the Rico Mountains has been made both on account of the economic importance of the district and as a necessity in connection with the areal geological mapping of the San Juan and adjacent mountains, now in progress. In the course of this work the Rico quadrangle was taken up in 1897 and finished, with the exception of the small area about Rico, where the geology was found to be so complicated as to require an accurate and detailed topographical base. It was also seen that an intelligent exploitation of the mineral resources of the district was practically impossible until such a geological map should be available.

In the summer of 1898 the topographical map was made, and on its completion the geological work was at once begun, but could not be finished before the snowfall of early winter. In the season of 1899 the work was completed. During the work of the three years mentioned Mr. Arthur C. Spencer was associated with the writer as assistant geologist. Messrs. Ernest Howe, R. D. George, and Jáson Paige served at different times as volunteer aids.

In 1897 Mr. C. W. Purington, assistant geologist, examined the ore deposits of the district, but the determination to make a special map and report rendered it desirable to have a correspondingly detailed study of the economic resources in the following year, and to this duty Mr. George W. Tower, jr., was assigned, as Mr. Purington had meanwhile resigned from the Survey. Before preparing his report upon the Rico district Mr. Tower also left the Survey to engage in private business. As some of the most complicated portions of the region, including the Silver Creek Valley, were not thoroughly understood during Mr. Tower's work, a further study of the ore deposits in the light of the geology will be carried on by F. L. Ransome in the season of 1900.

CHAPTER I.

OUTLINE OF THE GEOLOGY.

By Whitman Cross.

LITERATURE CONCERNING THE REGION.

Hayden Geological Survey.—The country adjacent to Rico was visited by geologists of the Hayden Survey in 1874 and 1876. In the former year the late F. M. Endlich examined the district to the east, the one hundred and eighth meridian, passing through Telescope Mountain, being apparently the general western boundary of his field of work. In 1876 W. H. Holmes made a rapid reconnaissance over an enormous area of the plateau country to the west. The complicated geology of the Rico uplift, coming on the border zone between the fields of different men working in different seasons, did not receive adequate attention, and the Hayden map of this area is, therefore, quite unsatisfactory.

From his report for the year 1874 it would appear that Endlich visited Blackhawk Peak ("Station 37"), approaching it from the east, but that he did not examine any other part of the mountain group. Since no benefit can come to the present report from a critical review of Endlich's inaccurate observations and misconceptions regarding the local geology, they will be passed over with brief comment. He published two profile sections running through Blackhawk Peak, but the data of these profiles, of the published map in the Geological Atlas of Colorado, and his statements of observations do not agree, and they are all decidedly erroneous in most particulars. What Endlich saw of the Rico dome structure was interpreted as a rather sharp anticline running along Silver Creek. Some of the intrusive sheets about Blackhawk Peak were observed, but it is difficult to understand on what basis the porphyry sheet of Hermosa Peak was extended westward along the divide to the summit of Telescope Mountain. Endlich later became the superintendent of the first smelter at Rico, but he published nothing further concerning the geology of the region.

The Hayden map of the western part of the Rico Mountains is the work of W. H. Holmes, and the inconsistencies in stratigraphy about the head of the Dolores River are due to the necessary adjustment between his work and that of Endlich. Holmes established a section of the Mesozoic formations to the west, which was expressive, adequate to the needs of the reconnaissance map, and in its general features is to-day recognized as correct. Endlich, on the other hand, had established an inadequate and partially incorrect stratigraphic section for the same formations, and where these two systems of mapping came together there was naturally a forced representation of unconformities by overlap which did not exist. This explains the drawing of the Hayden map about the Rico Mountains. The porphyry masses of Elliott Mountain and Calico Peak were observed by Holmes from a distance and represented with some approximation to correctness.

John B. Farish.—In 1892 John B. Farish read a paper before the Colorado Scientific Society entitled On the Ore Deposits of Newman Hill, near Rico, Colorado.[1] The description of the ore deposits was preceded by some general remarks on the geology. The structure of the mountains was recognized by Farish as a domal uplift, and concerning it he says: "The elevation of the mountains was associated in its origin with the intrusion of a laccolitic mass of porphyritic diorite, which may be seen a short distance above the town. The amount of upheaval at the center of the uplift was several thousand feet. Its longer axis is at right angles to the course of the river, and is so coincident with the corresponding axis of the laccolite." It is not evident what outcrops were assumed to represent the large laccolith, but the sheet at the northern base of Newman Hill is referred to as an offshoot from it. The rock of the laccolith is said to be probably a "hornblende-augite-porphyrite (a porphyritic diorite)," on the authority of R. C. Hills. Faults were recognized by Farish, but probably only the minor ones of Newman Hill.

The sedimentary rocks about Rico are stated by Farish to be "Lower Carboniferous and Carboniferous proper," but the grounds for the determination are not given.

T. A. Rickard.—A detailed description of the Enterprise mine was published in 1896 by T. A. Rickard, then superintendent of the mine.[2] In this paper there are but few statements concerning the general geology. The strata about Rico are said to be fossiliferous and to belong to the Lower Carboniferous, and the common igneous rock is called porphyrite, with a concise description by R. C. Hills. Rickard refers to "a large dike of porphyrite" crossing the valley north of Rico, "making a fault which breaks the continuity of the country on either side." It would appear that this reference, as well as that of Farish, above noted, concerning the supposed laccolith, must be to the mass of schists with small dikes of hornblendic porphyry; but the position and importance of the fault are not further indicated.

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[1] Proc. Colorado Sci. Soc., Vol. IV, pp. 151-161.

[2] Trans. Am. Inst. Min. Eng., Vol. XXVI, pp. 906-980.

The papers of both Farish and Rickard deal mainly with the Enterprise mine and give many important details of the geology of Newman Hill, as thus revealed, to which reference will be made further on in describing this locality.

Telluride and La Plata folios.—The first results of the resurvey of the San Juan region, now in progress, are contained in the Telluride folio, No. 57 of the Geologic Atlas of the United States, issued in 1899. The southwestern corner of the Telluride quadrangle is situated almost at the northern base of the Rico Mountains, 4 miles north of Telescope Mountain. While the structure of the Rico Mountains extends into the Telluride quadrangle but a very short distance, the Mesozoic formations there exposed are the same seen at Rico, and the discussion of several of them is fuller in the folio than in the present report. But the most important bearing of Telluride geology upon that of the Rico Mountains is in connection with the intrusive monzonite porphyries, the stocks of granular rocks, and the surface volcanic series of the San Juan. The age of the Rico dome, the conditions at Rico at the period of its elevation, and other problems of local geology must be discussed in the light of the facts observed in the Telluride quadrangle.

The La Plata Mountains, situated mainly in the quadrangle of the same name and lying directly south of Rico some 16 to 25 miles, are so analagous to the Rico Mountains in general character that their description in the folio now in press (Geologic Folio No. 60, La Plata) is in a measure supplementary to that of the Rico group. The domal structure is simpler because there are no profound faults, the intrusive porphyries are of the same general character as those of Rico, and there are several stocks of granular rocks, monzonite, diorite, and syenite, cutting the porphyry sheets.

GENERAL DESCRIPTION OF THE MOUNTAINS.

Physiographic relations of the mountain group.—The Rico Mountains form a small, compact group of peaks resulting from the deep dissection of a local dome-like uplift of sedimentary and intrusive igneous rocks. This uplift appears on the eastern border of the Dolores Plateau, which is continuous westward with the Great Sage Plain of Utah, extending to the brink of the Colorado Canyon. The termination of the Dolores Plateau on the line passing through the Rico and La Plata mountains is due to a change in the attitude of the underlying sedimentary formations. Beneath the plateau they are approximately horizontal, but on the line mentioned they come under the influence of the monoclinal folding which has taken place in a broad zone adjacent to the San Juan Mountains.

The relations of the Rico Mountains to the Dolores Plateau are well illustrated by the topographic map of the Rico quadrangle. On that sheet the plateau surface is shown crossing the western boundary with a general elevation of about 9,400 feet, rising very gradually for several miles and then merging into a gently dipping surface on the borders of the Rico uplift, a short distance beyond the limits of the [illegible] map. To the east of the Rico Mountains the countr[illegible] undulating character, modified by a few prominen[illegible] igneous rocks. Pl. I exhibits the character of the zone [illegible] Rico and San Juan Mountains as seen from near the summit of Blackhawk Peak, the highest of the Rico group. At a distance of 8 or 10 miles rise the very rugged peaks of the San Juan. In the middle ground, on the right, is Hermosa Peak, caused by an intruded porphyry mass which is probably continuous with the white cliffs of Flat Top, seen on the left hand of the view. The low mountain with a light-colored band on its southern face, about 2 miles from Blackhawk Peak, presents a beautiful section of the white La Plata sandstone, dipping gently away from the point of view under the influence of the Rico uplift.

Another view of this belt of country east of the Rico Mountains is presented in Pl. II, a photograph taken from the knoll (11,886 feet) on the divide northeast of Telescope Mountain, looking east toward Hermosa Mountain. In Pl. XIX (p. 148) is shown the character of the country between the Rico and La Plata mountains. The crest line of the central portion of the view is Indian Trail Ridge, the divide connecting the two mountain groups, which is made up of red Triassic strata dipping at a low angle southwest and passing under the Jurassic and Cretaceous beds on the right-hand border of the view.

Drainage system and vegetation.—The Rico Mountains are cut into two nearly equal parts by the Dolores River, which receives all the drainage from within the group and from its northern and southern slopes. On the western side a portion of the drainage is into the West Dolores River, and on the east heads one of the tributaries of the Animas River.

Timber line in the Rico Mountains lies between 11,500 and 12,000 feet, and its course may be traced in several of the illustrations accompanying the report. The trees and shrubs are those common in the mountains of Colorado, with perhaps greater variety than usual in the lower sheltered valleys.

Details of physiography.—A glance at the accompanying map (Pl. XXII, in pocket) shows that the Rico Mountains consist of a circle of high and rugged peaks, divided into two crescent-shaped halves by the Dolores Valley. There are twelve peaks, each exceeding 12,000 feet in elevation above sea level, and the narrow crest connecting them rarely sinks below 11,500 feet on either side of the river. In passing

RECENT GEOLOGIC HISTORY.

Many of the features of post-Glacial geology at Rico are inseparable in origin from similar features of Glacial and earlier time, since in those parts of the area that were not covered by the ice similar processes of general erosion and of local deposition were active throughout the Glacial stage. For this reason, in classing the following phenomena as recent, there is no intention of limiting their age to the post-Glacial, but rather to indicate that the conditions which have produced them have continued down to the present time. The recent phenomena of the Rico region may be classed as those of erosion and those of deposition. The latter will include landslides, talus and avalanche materials, river gravels, and spring deposits.

Post-Glacial erosion.—If the gravels observed by Mr. Cross at an elevation of 700 feet above the river on the northern edge of the monzonite are really of glacial origin, they indicate a much greater accumulation of such débris in the Dolores Valley than would be suggested by any other occurrences. But even if they are glacial, the work of the river seems to have been largely the removal of the gravels, with little cutting into the underlying rock. In Deadwood and Allyn gulches the streams have cut down through the unconsolidated gravels of glacial origin, but this is a task which they could have easily accomplished in a short time. Similar indications of the small effect of post-Glacial bed-rock erosion are seen in Silver Creek, where the stream has locally excavated narrow canyons in the wider valley of glacial origin, but these canyons have in no instance exposed the bed rock to a depth of more than possibly 20 feet, and in many places the stream is working upon débris of very recent origin, which has been thrown into its channel from the side gulches and ravines. All the evidence serves to point to the recency of the glacial occupation and to the small amount of erosion which has since ensued. The present topography is in no essential feature different from what it was previous to the accumulation of the ice. Before that the streams had found their present courses and had practically assumed their present grades. Greatly in excess of any topographic changes due to erosion are those attributable to the constructional features which are discussed in the following paragraphs.

Varieties of surface deposits.—The surface deposits at Rico are of very diverse character and origin, and, as has been seen in the discussion of the glacial gravels, they are not easily separable as to origin. They are very troublesome to the geologist, since they cover the central part of the region to such an extent that it has been found impossible to work out the geology of the solid rocks underlying. Consequently it is necessary to represent them on the map, and for this purpose five distinct patterns have been used to distinguish (1) areas made up principally of landslide material; (2) valley gravels; (3) alluvial cones; (4) spring deposits; (5) materials of other origin, such as avalanche, glacial, and surface wash.

Landslides.—The most important surface deposits in the Rico Mountain are of landslide origin. One such slide has materially altered the grade of the Dolores River north of Rico, others have changed the profile of Horse Gulch, while still others lend their characteristic pseudo-glacial topography to the mountain slopes in several places. This feature of the Rico region has been specially studied by Mr. Cross, and its description and discussion are given a separate chapter in this report.

Talus.—Accumulations from the wasting of cliffs are related in origin to landslides, but are composed of many small blocks loosened by frost action or by heavy rains, whereas landslides, though they may eventually become very much broken, are at first essentially large masses. Talus forms are of frequent occurrence at Rico, and while in many cases, especially in the lower parts of the mountains, their even slopes are covered with vegetation, in other cases they are entirely bare and then suggest the manner in which they were formed, namely, by the rolling and sliding of loose rock fragments under the action of gravity. They are well illustrated in several of the accompanying plates, particularly in Pl. VI (p. 28), showing the steep talus at the base of the Sandstone Mountain cliffs, and in the view of Calico Peak (Pl. VII, p. 32) and that of Blackhawk and Dolores peaks from the north (Pl. IV, p. 24). The long talus streams upon the west slope of Nigger Baby Hill are largely derived from the mines which are situated at their heads, but the whole adjacent slope is covered by natural talus or wash through which very few outcrops appear.

Related to talus are the materials dislodged by avalanches and deposited where their force is spent. Much of the loose material upon Newman and C. H. C. hills has been brought down in this way, and the paths which have been cut through the timber upon the western slope of Dolores Mountain may be made out from the photograph of this slope (Pl. III, p. 22). Other ravines than these, which have been the tracks of snowslides, may be seen at various places. Some of the best marked are on the south side of Burnett Creek, upon the flank of Landslip Mountain.

The deposits of Papoose Gulch and in the head of Marguerite Draw west of Mount Elliott have been mentioned in discussing the glacial phenomena, where they are considered as connected with former great snow banks. Probably this is, in part at least, their true origin, but avalanches may have been also concerned in their formation.

Surface wash.—In regions where the agents of erosion have been as active as at Rico rocks do not decay in situ by surface weathering, and consequently residual soils, such as cover the rocks in many low-lying regions, do not accumulate. Surface wash is composed almost entirely of fragments derived from the higher slopes of the mountains, or from the disintegration of landslides which, gradually moving toward the valleys under such effective aids to gravity as snow, rain, and frost, have been spread in varying thickness over extensive slopes, hiding the underlying formations as completely as have the more massive surface deposits. As may be inferred from such an origin, the materials of the surface wash are as a rule more completely pulverized than the other forms of surface deposits.

As in the case of all the surface deposits, the representation of surface wash on the map is generalized and the indicated boundaries are to be taken as approximate. The symbol under which they are included is intended to apply to all areas not referable to the three classes of landslides, valley deposits, and alluvial fans. It thus comprises the materials of mixed origin covering Newman Hill and the opposite slope west of the river.

Valley deposits.—The valley deposits of the Rico region comprise the gravels of the present flood plain of the river. They consequently occur in a band across the area and bordering the river, but interrupted above Horse Gulch by the great landslide at the base of C. H. C. Hill. This mass of rock which has been projected into the valley has pushed the stream against the western bank of the canyon, where it is now cutting in the solid rocks of the lower Hermosa. As may be seen by referring to the topographic map, it has interfered with the natural grade of the river, which is now abnormally steep adjacent to the slide block upon the lower side and as notably low in the reach upstream from it. The landslide at first formed a dam across the river, causing slack water for perhaps a mile and a half upstream. From the even spacing of the contours below the dam it is believed that the original stream bed at the lower end of the Burns meadow is approximately 75 feet below the present position of the river, the same figure representing the thickness of the materials deposited by the river at this place. If the same spacing which is noted below the landslide were continued upstream the 9,050-foot contour would have approximately its present position, so that it may be taken to represent about the upper limit of the effect of the landslide in changing the stream grade. From the dam to the present crossing of this contour the distance is slightly in excess of 1 mile, and the fall of the stream is not more than 25 feet, or less than one-fourth the normal fall for this distance. The northern edge of the landslide block and the flat above it are shown in Pl. XVI (p. 142).

The materials of the valley deposits are coarse gravels and sands which the river has derived from its tributaries and which it has rolled along and distributed within its immediate valley.

Alluvial fans.—The steeper gulches which open directly into the

Dolores Valley have all afforded detritus faster than the river has been able to carry it off, so that the débris brought down by the side streams has accumulated in conical banks at the mouths of the gulches. Such accumulations are commonly known as alluvial fans. They are a characteristic feature of the union of streams of steep grade with those of low declivity, since the transporting power of the steeper streams is suddenly diminished when their grade is reduced. The side streams at Rico do not at ordinary times carry any appreciable load of gravel, transportation being confined to times of flood. Heavy showers and cloud-bursts sweep débris into the steep gullies, and this, carried down to the main valley, is dropped, and the channel of the stream becomes inclosed by natural dikes, so that on becoming choked at any time the torrent will take a new course and, changing from time to time, will finally have swept through an arc limited by the valley walls and varying in width from 90 to 120 degrees. It is by thus changing its channel that the stream is able to build up the conical heap at its mouth.

At Rico many of the characteristics of alluvial fans are beautifully illustrated. An inspection of the map will show the extent of the principal ones and the different relative positions of the stream channels upon the cones, and in several cases the contouring indicates the lines of former channels. The typical appearance of the alluvial fans is shown in Pl. XXI, from a photograph of the Aztec fan taken at a point upon the east side of the river near the wagon road. In this case the present channel is central. Other abandoned courses may be made out in the aspens on the north side, and another exists along the southern edge but can not be seen in the illustration. An interesting feature also shown in this photograph is the smaller fan which has been formed in front of the larger one. From the relations exhibited it appears that the great fan originally extended farther to the east than at present, but that the river in shifting its course was thrown against its base and cut away its lower portion, producing the steep bank now exhibited. During this period of cutting the channel on the fan probably had a location different from the present. Since the channel was located at the position which it now has a secondary fan has been formed by material, a portion of which seems, from the depth of the channel, to have been derived from the upper part of the main fan.

Other fans than those represented occur in Silver Creek at the mouth of Allyn Gulch and of the next gulch above upon the south side. Also a portion of the surface materials upon the hillside west of Rico may have been formed in the same manner as the fans of the lower valley, which they very closely resemble as topographic features. These have not been distinguished from the adjacent surface débris.

Calcareous spring deposits.—The Rico Mountains are well watered, and even in the driest seasons most of the gulches contain very considerable streams which are fed by springs. The water of the springs is usually impregnated either with lime or with iron, probably of rather superficial origin, and locally these ingredients are frequently present in sufficient amounts to separate from solution and form deposits upon the surface or in the interstices of gravel or other loose surface materials. In some cases the waters, besides their mineral contents, are impregnated or accompanied by gases, such as sulphureted hydrogen and carbonic acid gas.

The generally calcareous nature of the spring water at Rico is a direct result of the richness of the prevailing sedimentary formations of the central region in carbonate of lime, but in most cases the amount of the mineral held in solution is not sufficient to give rise to important deposits of tufa. There are, however, several such deposits which are situated upon the lower slopes in localities where loose materials cover the solid rock for some distance above the springs. From this relation it seems likely that the waters travel underneath the surface of the ground from the higher elevations and, percolating through the loose surface materials, dissolve en route carbonate of lime, which they redeposit upon emerging at the surface, partly by evaporation and loss of carbonic acid and partly through the agency of the animals and plants which inhabit the boggy places about the springs. The lime is frequently deposited in such a way that ponds are formed, and in these small snails find a congenial habitat, the shells of successive generations gradually adding to the growth of the lime deposit. Moss growing in the bogs is continually saturated in the calcareous water, and becomes at first coated but finally entirely impregnated with the lime, giving rise to a spongy mass which is often found near the lime springs. Grasses, leaves, and twigs falling where the water can trickle over them are quickly entombed, and upon decaying leave their characteristic forms impressed upon the resulting rock. Leaf impressions may be found at almost any of the springs; they are especially well shown in the deposits above the wagon road south of Horse Gulch.

The principal deposits of calcareous tufa have been outlined on the map, by reference to which their extent and distribution may be seen.

At one locality the tufa has been quarried for a kiln and has found a considerable use, since it is conveniently located and produces lime of good quality.

Ferruginous deposits.—Iron-bearing springs occur at several places in the Rico Mountains, and have left local deposits of iron oxide, cementing surface débris and forming what is commonly known as "iron cap." Though occurring at other places, these ferruginous conglomerates are especially in evidence in Silver Creek above the Fort Wayne tunnel, in the upper part of the northern and western branches of Horse Gulch, and in the lower part of Horse Gulch at the base of the northern landslide area. Their origin is probably connected with the oxidation of iron pyrites, but their occurrence can never be safely taken as a clue to the proximity of large bodies of that mineral.

Gas springs.—Emanations of carbonic acid gas and of sulphureted hydrogen accompany many springs of water in the Rico region. The former is continually escaping in large quantities in the central part of the dome, while the latter is noted in many places on the west side of the mountain group in the drainage of Stoner and Bull creeks. Both gases doubtless have their origin in chemical changes which are going on at a greater or lesser depth beneath the surface, and the waters with which they are associated may or may not be of deep-seated origin. In some places they certainly are not, for in the case of the sulphur springs the water increases and diminishes with the humidity or dryness of the season, and at certain times the flow of water ceases entirely, but the gas continues to escape. It appears that in such instances the gases have found the same channels along which the waters are circulating and that the two mix and escape together. In like manner it is notable that the carbonic acid gas, which is escaping in large quantities in various places, is far in excess of the amount which can be absorbed by the water with which it issues, and in mine workings the gas is frequently encountered where it flows up from crevices without any water at all. In one of the borings of the Atlantic Cable Company, made several years ago, a flow of gas was tapped which, being confined, is said to have had a pressure of more than 50 pounds and to have maintained it, with slight decrease, to the present time. A similar pressure is reported to have been shown by gas encountered in a bore hole in the Rico-Aspen workings.

Several tunnels in the west bank of the Dolores at Rico have struck carbonic acid gas escaping from many fissures in the highly shattered rocks in the vicinity, and a spring of water strongly charged with this gas bubbles up through the gravels of the river bed not far from the Shamrock tunnel.

Several of the carbonic springs at Rico are locally known as "soda springs," and, while no analyses have been made of their waters, there is no reason for doubting the correctness of this designation. Their waters are highly charged with gas, an excess of which escapes in the form of bubbles, and are cool and of a delicious flavor, resembling, in this respect, the waters of known soda springs at other localities in Colorado.

COLORADO GEOLOGICAL SURVEY

DEPARTMENT OF NATURAL RESOURCES

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AND

THE COLORADO DIVISION OF PLANNING

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ENVIRONMENTAL GEOLOGY NO. 4

PRICE $1.00

S U M M A R Y

There is a possibility that natural resources may be discovered or further developed in any of the geologic units delineated by the principal map. Therefore, consideration must be given to the diverse future needs in areas of high development potential. The following examples point up the multiple use potential for some of the map units.

1. Alluvial deposits are a primary source for construction materials, such as sand and gravel, and are commonly found in stream valleys which are suitable for agricultural and residential development. Abandoned quarries can be developed into recreation sites.

2. Sedimentary rocks are host for fuel and energy resources (uranium, coal, gas and oil), and these rocks underlie many existing large communities in the Planning District.

3. Igneous, metamorphic and volcanic rocks locally yield significant amounts of metallic minerals. These areas are also attractive to recreational community developers.

Massive land movements or other unstable surface conditions are found most commonly in areas having moderate to extreme topographic relief and abundant moisture. However, this generalization is too restrictive for Planning District 9. The Mancos and Lewis shales are potentially troublesome even in areas of low topographic relief. These clay-rich rocks are seen to creep or move slowly down gentle slopes where they are poorly drained and/or altered by construction. The potential for unstable surface conditions must be evaluated carefully for every proposed development site.

The need for soil investigations at all construction project sites is seen dramatically throughout the District. Many public and private buildings have structural damage which has been caused, at least in part, by swelling or settling soils. The life of any structure can be prolonged significantly by proper foundation design based on good soil engineering data.

General areas of flood danger or erosional hazards are found in association

with all drainage basins located within Planning District 9. The history of flooding within the District may fail to properly emphasize the importance of this observation. However, as the population density increases, so will the number of structures situated on flood plains. Planning efforts must take this fact into consideration and regulate development on flood plains to prevent future tragedies and economic loss.

Areas of high water table, both permanent and seasonal, are found throughout the District. This troublesome feature is related directly to geology and precipitation. Little control is available for regulating precipitation, but geologic investigations will delineate areas where rock materials have poor permeability and can point up corrective measures which will enable developers to make safe use of such land.

The text of the report clearly points up the fact that not all rocks nor physical settings are suitable for solid waste disposal sites. Geologic evaluations must be made to determine whether the rock material in question is workable and will provide an effective seal, and whether there is any danger of pollution to a community water supply. With these guidelines, planners can be aware of special studies needed to meet public health standards.

There is a distinct possibility that mine dumps found throughout the District may be contributing to environmental pollution or presenting hazards to the unwary developer. The intensity of the problem will be related to the type of mine (such as the subsidence or the water contamination potential associated with coal mines) and the proximity of the mine to streams or water bearing rock units. Thorough investigations and reclamation projects may have to precede development work in some of the intensively mined areas within the District.

Many critical geologic factors affecting planning and development are explained in the text of the report. This information provides guidelines to those responsible for protecting public interests within the District. Application of this data will help to ensure safe, efficient and environmentally sound land use decisions. In summary, the need is stressed for site-oriented geologic and engineering investigations to evaluate problems and provide solutions for specific land use proposals.

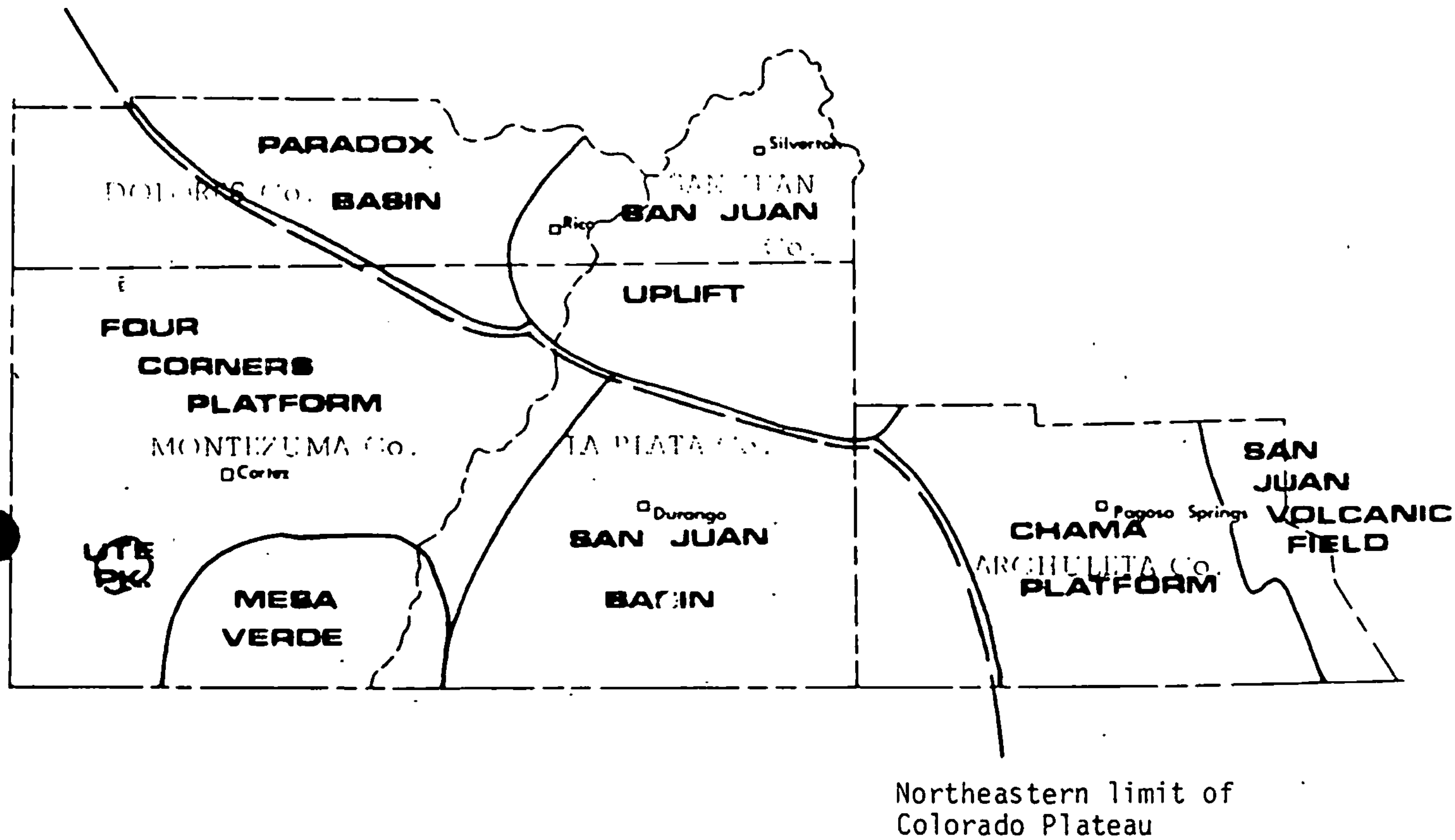
PHYSIOGRAPHIC FEATURES

The five county area which comprises Planning District 9 is situated in the southwest corner of Colorado. The Continental Divide is located near the northeast side of the District - lying within parts of the eastern sides of Archuleta and San Juan Counties. Elevations are seen to range (southwest to northeast) from 4,900 to 14,250 feet above sea level. The mean elevation is approximately 7,500 feet. The region can be described as mountainous, although the western and southern areas are part of the large physiographic province called the Colorado Plateau (Figure 3). The plateau region is dissected by drainage patterns which provide topographic continuity to the rugged nature of the alpine region. Principal rivers flow in south-southwest directions across the region with the exception of a part of the Dolores River which flows northwest through the northwest corner of the District.

GENERAL GEOLOGY

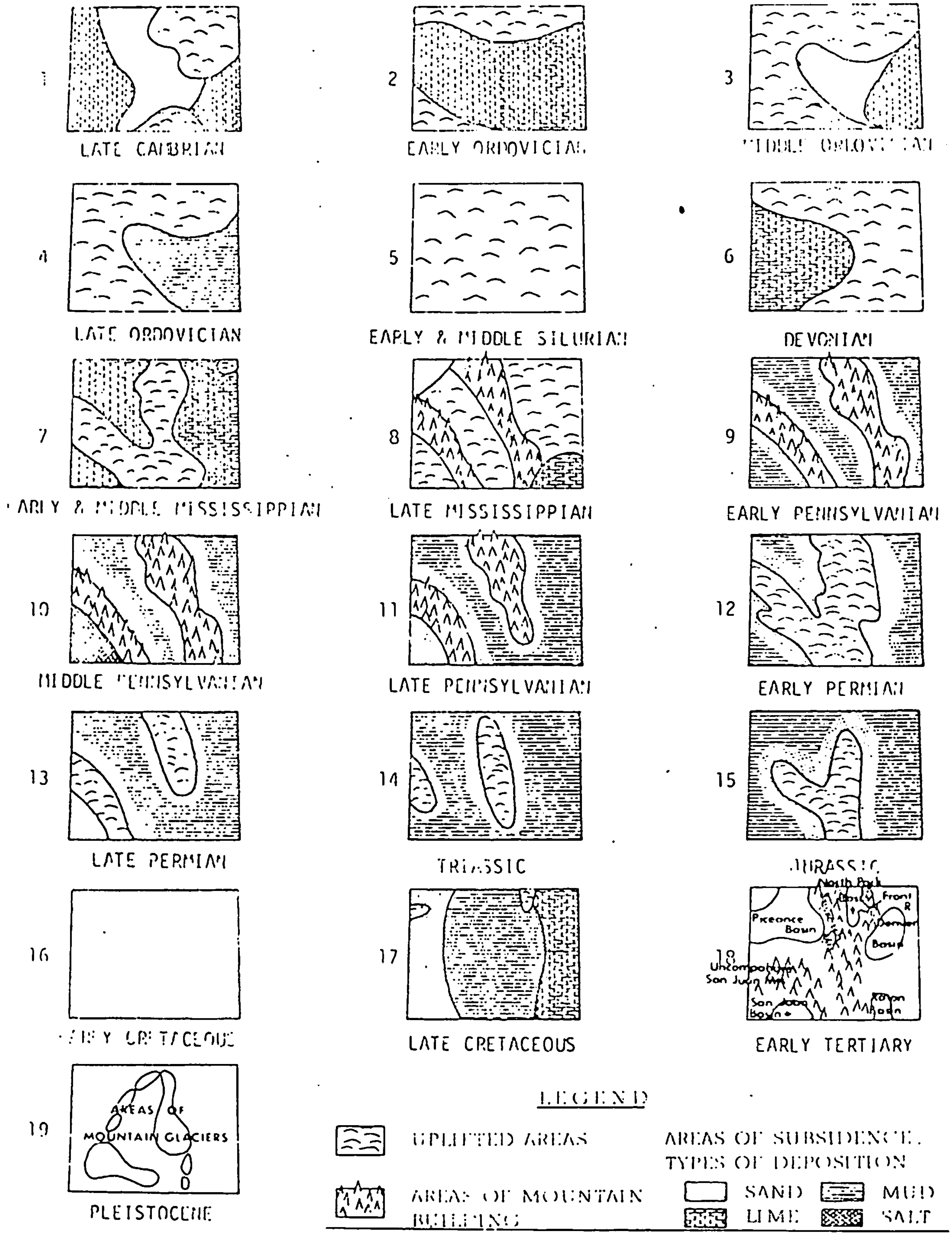
Figure 4 illustrates the geologic evolution of the State of Colorado and lists the geologic events for Planning District 9 in the order of occurrence. This synopsis shows the development of the various geologic units which eventually formed the present features of the area. A numerical cross reference is provided for the two parts of Figure 4 so that comparisons can be made between local and regional geologic events.

The geologic history of the Earth goes back approximately four billion years when the Earth was probably nothing more than a molten mass. The geologic history of interest to this report began about two and one-half billion years ago during the Late Precambrian Era as masses of various types of sedimentary and igneous rocks were repeatedly formed, buried, altered, uplifted and injected with new igneous bodies. About 600 million years ago, the first well-defined geologic periods began. The first was the Cambrian Period during which sand and lime accumulated in the sea which covered the District. Approximately one hundred million years later, the



MAJOR PHYSIOGRAPHIC FEATURES OF PLANNING DISTRICT 9

Figure 3



GEOLOGIC EVOLUTION OF THE STATE OF COLORADO

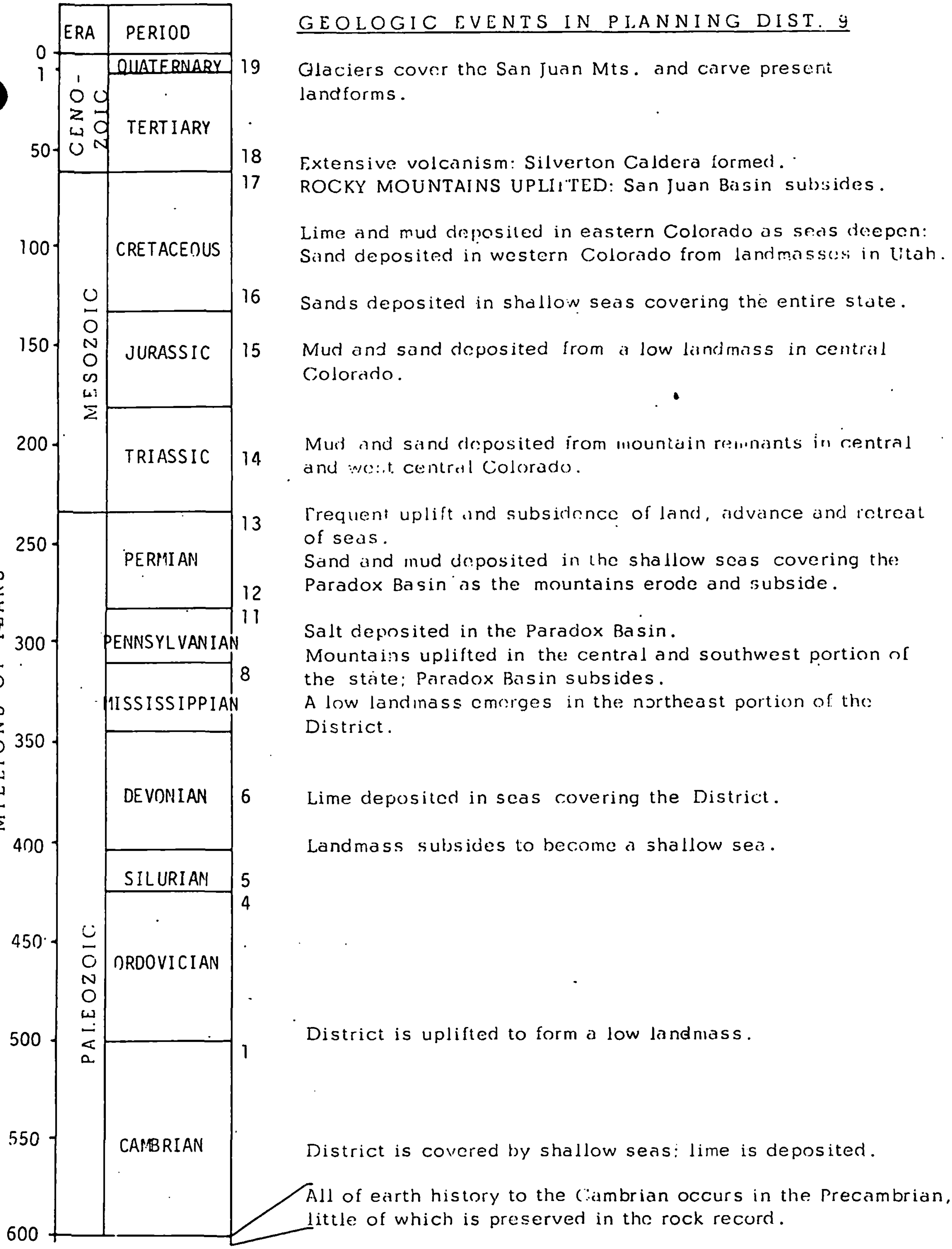

GEOLOGIC EVENTS IN PLANNING DIST. 9
ERA
PERIOD
MILLIONS OF YEARS
0
1
50
100
150
200
250
300
350
400
450
500
550
600
CENO-ZOIC
MESOZOIC
PALEOZOIC
QUATERNARY
TERTIARY
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
19 Glaciers cover the San Juan Mts. and carve present landforms.
18 Extensive volcanism: Silverton Caldera formed.
17 ROCKY MOUNTAINS UPLIFTED: San Juan Basin subsides.
Lime and mud deposited in eastern Colorado as seas deepen: Sand deposited in western Colorado from landmasses in Utah.
16 Sands deposited in shallow seas covering the entire state.
15 Mud and sand deposited from a low landmass in central Colorado.
14 Mud and sand deposited from mountain remnants in central and west central Colorado.
13 Frequent uplift and subsidence of land, advance and retreat of seas.
Sand and mud deposited in the shallow seas covering the Paradox Basin as the mountains erode and subside.
12
11 Salt deposited in the Paradox Basin.
Mountains uplifted in the central and southwest portion of the state; Paradox Basin subsides.
8 A low landmass emerges in the northeast portion of the District.
6 Lime deposited in seas covering the District.
Landmass subsides to become a shallow sea.
5
4
District is uplifted to form a low landmass.
1
District is covered by shallow seas; lime is deposited.
All of earth history to the Cambrian occurs in the Precambrian, little of which is preserved in the rock record.

Figure 4

Ordovician Period began with the gradual uplift of the region effecting the withdrawal of the sea and terminating the deposition of sediments. The region remained positive (a land area) throughout the Silurian Period. Slightly more than 400 million years ago (Devonian Period), the area was submerged and lime sediments accumulated in the shallow sea. Later, during the Mississippian Period, a broad region was uplifted to form mountain ranges in approximately the same location as the present Rocky Mountains. During the Pennsylvanian and early Permian Periods, the southwestern part of the District was subjected to alternating times of emergence and submergence. Shallow marine sediments consisting of sand, clay and salt accumulated in the region. Between 250 and 130 million years ago, Late Permian to Early Cretaceous time, the pattern of alternating uplift and subsidence of the land continued. Sediments forming in these seas included sand and clay, but not evaporites such as salt and gypsum. Shallow seas covered the entire State during the Cretaceous Period, and most of the sedimentary rocks that are found in the area today were deposited during that time. About 70 million years ago, the Tertiary Period began with extensive volcanism and mountain building movements. During that period, the San Juan Mountains were formed and the San Juan Basin subsided to form a small sea. This sea was probably an inland sea much as the Great Salt Lake is now. It was during this time that the Rocky Mountains were uplifted to their present position. Approximately 1 million years ago, during the Quaternary Period, much of the area was covered by mountain glaciers which carved the present land forms. In Recent Time, erosion of these land forms has produced the topographic relief seen today.

HOW TO USE THIS REPORT

This report has been prepared specifically for Planners and other Public Officials who share the broad responsibilities for making safe, effective and environmentally sound land use decisions. It has been assumed that those reading

PA Guidance
EPA Region VIII
August 1993

ATTACHMENT III

CERCLA ELIGIBILITY WORKSHEET

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URS
Project No. 41881
Log No. 41 ,60 ,B1028
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PA Guidance
EPA Region VIII
August 1993

CERCLA Eligibility Worksheet

Site Name Rico - Argentine

City Rico State Colorado

EPA ID Number COD980952519

Note: The site is automatically CERCLA eligible if it is a Federally owned or operated RCRA site.

I. CERCLA Eligibility

Did the facility cease operations prior to November 19, 1980? No

If YES, then STOP. The facility is probably a CERCLA site.
If NO, continue to part II ______

II. RCRA Deferral Factors

Did the facility file a RCRA Part A application? No

If YES:

1. Does the facility currently have interim status? ______
2. Did the facility withdraw its Part A application? ______
3. Is the facility a known or possible protective filer? (filed in error) ______
4. Does the facility have a RCRA operating or post closure permit? ______
5. Is the facility a late (after 11/19/80) or non-filer that has been identified by the EPA or the State? (facility did not know it needed to file under RCRA) ______

Type of facility:

Generator____ Transporter_____ Recycler ____

TSD (Treatment/Storage/Disposal) _____

If all answers to questions 1, 2, and 3 are NO, STOP. The facility is a CERCLA eligible site.

If answer to #2 or #3 is YES, STOP. The facility is a CERCLA eligible site.

If answer to #2 and #3 are NO and any other answer is YES, site is RCRA, continue to part III.

III. RCRA Sites Eligible for the NPL

Has the facility owner filed for bankruptcy under Federal or State laws? No

Has the facility lost RCRA authorization to operate or shown probable unwillingness to carry out corrective action? No

Is the facility a TSD that converted to a generator, transporter or recycler facility after November 19, 1980? No

IV. Exempted substances:

Does the release involve hazardous substances other than petroleum? Yes

V. Other programs: The site may never reach the NPL or be a candidate for removal. We need to be able to refer it to any other programs in EPA or state agencies which may have jurisdiction, and thus be able to effect a cleanup. Responses should summarize available information pertaining to the question. Include information in existing files in these programs as part of the PA. Answer all that apply.

Is there an owner or operator?

Yes. Rico Development Corp.

NPDES-CWA: Is there a discharge water containing pollutants with surface water through a point source (pipe, ditch, channel, conduit, etc.)?

Acid-mine water discharge

CWA (404): Have fill or dredged material been deposited in a wetland or on the banks of a stream? Is there evidence of heavy equipment operating in ponds, streams or wetlands?

Settling ponds on banks of Dolores River, Silver Creek

UIC-SDWA: Are fluids being disposed of to the subsurface through a well, cesspool, septic system, pit, etc.?

TSCA: Is it suspected that there are PCB's on the site which came from a source with greater than 50 ppm PCB's such as oil from electrical transformers or capacitors?

FIFRA: Is there a suspected release of pesticides from a pesticide storage site? Are there pesticide containers on site?

RCRA (D): Is there an owner or operator who is obligated to manage solid waste storage or disposal units under State solid waste or ground water protection regulations?

UST: Is it suspected that there is a leaking underground storage tank containing a product which is a hazardous substance or petroleum?

COLORADO NATURAL HERITAGE PROGRAM
c/o University of Colorado Museum
Hunter 115, Campus Box 315
Boulder, Colorado 80309-0315
(303) 492-4719 • Fax (303) 492-5105

RECEIVED
APR 2 5 1994
URS/ARCS

The Nature Conservancy

April 13, 1994

Mike Carr
URS Consultants, Inc.
1099 18th Street, Suite 700
Denver, CO 80202

Dear Mr. Carr:

The Colorado Natural Heritage Program (CNHP) is in receipt of your recent request for information regarding the Brighton-Ft. Lupton Landfill and the Rico-Argentine Mine. In response, CNHP has searched it's Biological and Conservation Datasystem for natural heritage resources (occurrences of significant natural communities and rare, threatened or endangered plants and animals) documented from T1N R66W and T40N R11W.

According to the information currently in our files, there are no occurrences of significant natural communities or rare, threatened or endangered species documented from within the four-mile radius of the Brighton-Ft. Lupton Landfill site. However, there is one occurrence of Eustoma russellianum (also known as Eustoma grandiflora, Showy prairie gentian, approximately 15 miles downstream, west of the South Platte River in the vicinity of Lyons Road, north of Colorado Hwy 66 and west of Road 23. This species is ranked very common globally, but is considered rare to uncommon in Colorado and is under review for federal listing. A 1989 report indicated that habitat for this species has been intensively grazed and/or cultivated over the past 100 years; causing concern that this species could be disappearing (Jennings, 1989).

aspen tree cactus

A review of the Rico-Argentine Mine project area indicated an occurrence of one significant natural community within the four-mile radius of the site, as well as two additional occurrences of significant natural communities within the 15-mile downstream limit. Populus angustifolia-Picea pungens/Alnus incana, a montane riparian forest, can be found along the east bank of the Dolores River within four miles of this project area. An occurrence of an Abies lasiocarpa/Alnus incana/Salix drummondiana montane riparian forest has been documented 1.5 miles up Priest Creek trail from the Dolores River. Both of these communities are ranked rare to uncommon both globally and in Colorado. Also, a 1991 field survey reported that threats to the community A. lasiocarpa/A. incana/S. drummondiana include erosion, flooding, and grazing (Kittel & Lederer). A Populus angustifolia/Cornus sericea montane riparian forest occurs along the Dolores River approximately 15 miles downstream. This natural community is ranked very rare globally and in Colorado. Alteration of the hydrologic regime may adversely affect these natural communities. — outside 4-mile

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While the information contained herein represents a thorough search of the CNHP's Biological and Conservation Datasystem, any absence of data does not necessarily mean that other natural heritage resources do not occur on or adjacent to the project site, but rather that our files do not currently contain information to document their presence. CNHP's datasystem is constantly growing and revised. Please contact CNHP for an update on this natural heritage information if a significant amount of time passes before it is utilized.

Sincerely,

Katie Pague

Katherine E. Pague
Information Manager

STATE OF COLORADO
Roy Romer, Governor
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WILDLIFE
AN EQUAL OPPORTUNITY EMPLOYER

Perry D. Olson, Director
6060 Broadway
Denver, Colorado 80216
Telephone: (303) 297-1192

151 E. 16th St.
Durango, CO 81301
303-247-0855

REFER TO

COLORADO DIVISION OF WILDLIFE

For Wildlife–
For People

June 6, 1994

Mark Carr
URS Consultants
1099 18th St., Suite 700
Denver, CO 80202

Dear Mr. Carr,

This letter is in reference to your request for State sensitive wildlife species in the Rico, Colorado area. I have conferred with Rich Lopez, District Wildlife Manager (CDOW), who works the Rico area. To our knowledge there are no threatened or endangered species resident in the Rico vicinity. The Boreal toad *(Bufo boreas)* may inhabit wetland stream or pond areas, but there have not been any studies conducted to verify their presence or absence.

The Dolores River above Rico experiences heavy fishing pressure. The Division of Wildlife stocks fish in the river through the town of Rico. The upper head waters of the Dolores support a viable native cutthroat trout fishery. Silver creek has virtually little aquatic life because of the heavily mineralized water below the mines (first two miles). The Division has stocked native cutthroat trout approximately 2 miles above the town in Silver creek and they are doing relatively well.

The Dolores River was one of the target drainages to re-introduce the River otter, a State endangered species, but to our knowledge they are not present this far up the Dolores River drainage.

If I can help you further with your project please feel free to ask.

Sincerely,

Ruth Lewis Carlson

Ruth Lewis Carlson
Habitat Biologist

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cc: Clark, Zgainer, Lopez

United States Department of the Interior

TAKE PRIDE IN AMERICA

BUREAU OF RECLAMATION
DENVER OFFICE
P.O. Box 25007
Building 67, Denver Federal Center
Denver, Colorado 80225-0007

IN REPLY REFER TO
D-5724
RES-3.20

May 25, 1994

Mr. Mike Carr
URS
1099 18th Street, Suite 700
Denver CO 80202

Subject: Water Quality and Sediment Data on the Dolores River

Dear Mr. Carr:

As per your request, I am enclosing the water quality and sediment data that Reclamation's Durango Office collected on the Dolores River. The samples span the period from 1989 through 1993. The data files are on the enclosed diskette in LOTUS® version 3.1 format. The water quality data are included in the file WTR-QUAL.WK3. The water quality data were analyzed at several different laboratories, which are identified in the data files. The sediment data are in the file named SEDIMENT.WK3. The sediment analyses were performed by the Geological Survey Geochemistry Branch Laboratory here in Denver.

As we discussed on the telephone, I am enclosing a copy of the preliminary draft of a report on the analysis of the Dolores data that I have been preparing. The report deals with the data collected through 1992. The additional water quality and sediment samples collected during 1993 were a result of the report. It should be noted that the enclosed report has undergone absolutely no review. I stopped work when it became apparent that the initial hypothesis on which the study was designed, *i.e.*, that the source of mercury in fish in McPhee Reservoir was in the Rico Mining District, was not supportable based on the data. There were several alternative hypotheses that could be investigated. One of these concerned air-borne mercury from powerplants to the southwest. An investigation conducted by the EPA's Environmental Monitoring and Support Laboratory in Las Vegas during 1977 indicated that the vast majority of the mercury emitted by the Four Corners Power Plant moved off site. A copy of the summary sheet from that report is also enclosed for your information. Another possibility was that the source of the mercury was a tributary nearer the reservoir. The 1993 samples focus on the lower reaches of the river. This aspect of the problem is not addressed in the report.

The enclosed report is very preliminary. It contains no discussion or conclusions. Any conclusions drawn from what is presented in the report will have to be your own. I will respond to any questions that might arise in relation to the material in the report. I can be reached at 303/236-3778.

Sincerely,

Jim Yahnke

Jim Yahnke
Hydrologist

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Enclosures

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Project No. 41881
Log No. 41,70,B1021
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DOLORES RIVER WATER QUALITY IMPROVEMENT STUDY
Sample Station Locations

REVISED May 23, 1994

SURFACE WATER STATIONS:

STATION	LATITUDE	LONGITUDE	DESCRIPTION
DRDOL01T	37-46-27.5 N	107-58-47.5 W	Barlow CK. near mouth at the bridge
DRDOL02T	37-46-37.5 N	107-58-43.75 W	Dolores River just above confluence with Barlow Ck.
DRDOL03T	37-43-31.25 N	108-01-48.75 W	Dolores River at Peterson Slide
DRDOL04T	37-45-30.0 N	108-07-38.75 W	Geyser Ck. near the mouth
DRDOL05T	37-47-18.75 N	108-05-10.0 W	West Dolores River approx.1/8 mile above Cold Ck.
DRDOL06T	37-40-02.5 N	108-02-12.5 W	Dolores River at Rico City Park
DRDOL07T	37-39-38.7 N	108-02-37.5 W	Scotch Ck. near the mouth just above the bridge
DRDOL08T	37-38-37.5 N	108-03-26.25 W	Dolores River at the Montelores Bridge
DRDOL09T	37-35-13.75 N	108-21-30.0 W	Dolores River approx. 1/8 mile above confluence with West Dolores River
DRDOL10T	37-42-01.25 N	108-01-42.5 W	Silver Ck. near the mouth at the bridge
DRDOL11T	37-43-25.0 N	108-01-50.0 W	Dolores River at the bridge above Rico
DRDOL12T	37-28-27.5 N	108-30-15.0 W	Dolores River at Dolores-USGS gauging station (sampled by Cortez)
DRDOL13T	37-37-16.0 N	108-03-42 W	Wildcat Creek near mouth
DRDOL14T	37-34-26.0 N	108-11-02 W	Bear Creek near mouth
DRDOL15T	37-30-59.0 N	108-22-47 W	Rock Spring Creek near mouth
DRDOL16T	37-39-28.0 N	108-18-37 W	Cottonwood Ck about 0.25 mi. above West Dolores Road bridge
DRDOL17T	37-34-14.0 N	108-38-01 W	Taylor Creek near mouth
DRDOL18T	37-35-08.0 N	108-09-19 W	Priest bulch near mouth
DRDOL19T	37-35-57.0 N	108-06-23 W	Roaring Forks Ck near mouth
DRDOL20T	37-35-24.0 N	108-18-55 W	Stoner Creek near mouth
DRDOL21T	37-34-43.5 N	108-14-02 W	Fish Creek near mouth
DRDOL22T	37-45-21.0 N	108-07-45 W	Geyser Ck Hot Spring near West Dolores River below Geyser Ck
DRDOL23T	37-46-47.0 N	108-05-14.5 W	Cold Creek near mouth
DRDOL24T	37-35-23.0 N	108-21-04.5 W	West Dolores River near mouth
DRDOL25T	37-28-06.0 N	108-30-26 W	Lost Canyon Creek near mouth
DRDOL26T	37-45-21 N	108-07-45 W	West Dolores River below Geyser Creek by Hot Spring.
DRDOL27T	37-43-42 N	108-15-39 W	Fish Creek below spring and 1/4 mi. below DRDOL21T.
DRDOL28T	37-40-00 N	108-02-07 W	SPring or old mine flow below Rico CO above Rico City Park.
DRDOL29T	37-43-31.25 N	108-01-48.75 W	Spring of flow out of old buried mine shaft by DRDOL03T.
DRDOL30T	37-30-20 N	108-23-20 W	Outflow from Wallace Reservoir at mouth prior to Dolores River.
DRDOL31T	37-45-46.25 N	108-59-26.25 W	Coal Creek 1.5 miles down from confluence of Barlow and Dolores River.
DRDOL32T	37-42-51.25 N	108-02-05 W	Horse Creek by ranger station north of Rico CO.
DRDOL33T	37-37-1.25 N	108-5-27.5 W	Tenderfoot Creek 1.5 miles below Wildcat Creek.
DRDOL34T	37-37-00 N	108-5-23.75 W	Tenderfoot Creek below pond 1.5 miles below Wildcat Creek.
DRDOL35T	37-34-31.25 N	108-17-30.06 W	Loading Pen Creek half-way between Taylor and Stoner Creeks.
DRDOL36T	37-35-37 N	108-08-7.5 W	Section House Creek 1 mile east if Priest Creek.
DRDOL37T	37-35-47.5 N	108-07-45 W	School House Creek about 1.5 miles east of Priest Creek at DRDOL18T.
DRDOL38T	37-35-33.75 N	108-07-53.75 W	Rio Lado about 1.5 miles east of Priest Creek at mouth to Dolores River.
DRDOL39T	37-34-59.12 N	108-17-47.5 W	Garrison Canyon Drainage and flows from Sutton and Knuckles Reservoir.
DRDOL40T	37-44-43.5 N	108-14-50 W	Ground Hog Creek prior to Fish Creek
DRDOL41T	37-44-00 N	108-44-00 W	Fish Creek above confluence with Ground Hog Creek
DRDOL42T	37-42-15 N	108-00-00 W	Silver Creek above mines-upper station (will show background quality)
DRDOL43T	37-42-15 N	108-00-50 W	Silver Creek below settling ponds-midpoint station
DRDOL44T	37-42-01.30 N	108-01-42.5 W	Deadwood Gulch Flow

STATION	LATITUDE	LONGITUDE	DESCRIPTION
DRDOL45T	NW1/4 SE1/4	SEC 5 T37 R14	Italian Canyon flow
DRDOL46T	NE1/4 SE1/4	SEC 33 T38 R14	Dolores River 1/2 mile below Station DRDOL30T
DRDOL47T	37-42-30.0	108-01-42.0	Abandoned geothermal well by Argentina Mine above Rico
DRDOL48T	37-43-25.0	108-01-50.0	Poor Boy Mine drainage
DRDOL49T	37-41-46.25	108-02-1.25	Dolores River just below confluence with Silver Creek (D-4)
DRDOL50T	37-41-20 N	107-01-42.5 W	Dolores River 2-miles above Rico (D-2)
DRDOL51T	37-38-28.5 N	108-02-7.5 W	Dolores River below Rico between tailings and old dump (at graveyard)
DRDOL52T	37-34-26 N	108-11-02 W	Dolores River below confluence with Bear Creek

SEDIMENT STATIONS:

STATION	LATITUDE	LONGITUDE	DESCRIPTION
D-1	37-46-37.5 N	107-58-43.7 W	Dolores River just above confluence with Barlow Ck.(DRDOL02T)
D-10	37-35-17.5 N	108-21-08.75 W	Dolores River about 1/8 mi. above confluence with W Dolores R
D-11	37-28-28.75 N	108-30-09.63 W	Dolores River at Dolores
D-12			Dolores River at Peterson Slide (DRDOL03T)
D-13			Dolores River at Dolores (D-11) (DRDOL12T)
D-14			Dolores River 1/2 mile below DRDOL30T (DRDOL46T)
D-15			West Dolores River near the mouth (DRDOL24T)
D-16			Dolores River below confluence with Bear Creek (DRDOL52T)
D-2	37-41-20.0 N	108-01-42.5 W	Dolores River 2-miles above Rico
D-3	37-43-25.0 N	108-01-50.0 W	Dolores River at the bridge above Rico (DRDOL11T)
D-4	37-41-46.25 N	108-02-01.25 W	Dolores River just below confluence with Silver Ck.
D-5	37-42-01.25 N	108-01-42.5 W	Silver Ck. near the mouth at bridge (DRDOL10T)
D-6	37-38-28.5 N	108-02-07.5 W	Dolores River below Rico at graveyard
D-7	37-39-53.75 N	108-02-30.0 W	Dolores River just above confluence with Scotch Ck.
D-8	37-39-38.7 N	108-02-37.5 W	Scotch Ck. near the mouth just above the bridge (DRDOL07T)
D-9	37-38-31.25 N	108-02-07.5 W	Dolores River at the Montelores Bridge (DRDOL08T)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/3-77-063	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE MERCURY DISTRIBUTION IN SOIL AROUND A LARGE COAL-FIRED POWER PLANT		5. REPORT DATE May 1977
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Alan B. Crockett and Robert R. Kinnison		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Las Vegas, Nevada 89114		10. PROGRAM ELEMENT NO. 1HD620
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency-Las Vegas, NV, Office of Research and Development, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada 89114		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA/600/07
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Seventy soil samples were collected on a radial grid employing sixteen evenly spaced radii and five logarithmically spaced circles, concentric around the Four Corners power plant. The soil samples were analyzed for total mercury using a Zeeman Atomic Absorption spectrophotometer. Residue levels were quite low compared to average soil residues and no statistically valid differences in mercury residue levels were detected between circles or radii using two-way analysis of variance techniques. F-ratios indicated: significant differences between circles, significant differences between radii, and significant complex interaction which could not be eliminated. Contours of iso-mercury concentrations show a relative high west of the plant near the ash ponds and another just east of the plant. The fate of the 510 kg of mercury emitted per year is not known, but it is not accumulating near the plant. Mercury emissions by U.S. coal-fired power plants amount to only 4% of the natural degassing loss in the U.S., and levels near power plants appear low. The significance of mercury emissions by power plants should be evaluated on a regional basis since the evidence shows no significant local elevation of mercury in soils or air.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Mercury*	Four Corners, NM	07E
residues	coal-fired power plants	08M
monitoring		10B
soil*		18B
power plants*		18H

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 14
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE A02-A01

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
Western Colorado Office
764 Horizon Drive, South Annex A
Grand Junction, Colorado 81506-3946

U.S. FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
764 Horizon Dr/So. Annex A
Grand Junction, CO 81506-3946

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IN REPLY REFER TO:

ES/CO:Nonfederal Informal Consultation
MS 65412 GJ

May 24, 1994

Michael Carr
Project Manager
URS Consultants Inc.
1099 18th Street, Suite 700
Denver, Colorado 80202-1907

Dear Mr. Carr:

This responds to your letter of April 20, 1994, requesting information on federally listed species in the Rico area. The following is a list of those species which may inhabit the area, or be effected by the proposed project.

Be advised that the Fish and Wildlife Service (Service) can enter into formal section 7 consultation only with another Federal agency or its designee. Thus, this is not to be considered an "official species list" but rather informal consultation. Informal consultation includes all contacts, discussions, correspondence, etc. between the Federal agency or its designated nonfederal representative, and the Service, that take place prior to the initiation of any necessary formal consultation. If requested, we will submit an official list to the lead Federal agency. That agency would be required under section 7 (a) (2) of the Act to initiate formal consultation if it determines that its action may affect any listed species or its critical habitat. Although applicants may fill the role of nonfederal representatives, the ultimate responsibility for compliance with section 7 remains with the Federal agency.

FEDERALLY LISTED SPECIES

Bald eagle	*Haliaeetus leucocephalus*
Peregrine falcon	*Falco peregrinus*
Mexican spotted owl	*Strix occidentalis lucida*
Colorado squawfish	*Ptychocheilus lucius*
Humpback chub	*Gila cypha*
Bonytail chub	*Gila elegans*
Razorback sucker	*Xyrauchen texanus*

We would like to bring to your attention species which are candidates for official listing as threatened or endangered species (Federal Register, Vol. 56, No. 225, November 21, 1991). While these species presently have no legal protection under the Endangered Species Act (Act), it is within the spirit of the Act to consider project impacts to potentially sensitive candidate species. Additionally, we wish to make you aware of the presence of Federal

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candidates should any be proposed or listed prior to the time that all Federal actions related to the project are completed.

FEDERAL CANDIDATE SPECIES

North American wolverine	*Gulo gulo luscus*
Northern goshawk	*Accipiter gentilis*
Flannelmouth sucker	*Catostomus latipinnis*
Roundtail chub	*Gila robusta*

The endangered and candidate fish species listed above do not occur in the project area, however, we consider the depletion of water from the upper Colorado River an adverse impact to the habitat for these species. Consequently, any activity authorized by the Environmental Protection Agency (EPA) that results in a net depletion of water from the upper Colorado River basin should trigger a "may affect" finding by the EPA and formal consultation with this office under authority of the Endangered Species Act.

We appreciate the opportunity to provide this information. If the Service can be of further assistance, please contact Michael Tucker at the letterhead address or (303) 243-2778.

Sincerely,

Keith L. Rose

Keith L. Rose
Assistant Field Supervisor, Colorado

pc: FWS/ES, Golden
CDOW, Montrose

MTucker:RicoSpl.ltr:052494

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
Colorado Field Office
730 Simms Street, Suite 290
Golden, Colorado 80401

IN REPLY REFER TO: ES/CO:Species List
Mail Stop 65412

JUN 17 1994

Michael V. Carr, Project Manager
URS Consultants, Inc.
1099 18th Street, Suite 700
Denver, Colorado 80202-1907

Dear Mr. Carr:

In response to your letter dated April 20, 1993, the U.S. Fish and Wildlife Service (Service) is providing the species list you requested for the Brighton-Ft. Lupton Landfill located in Weld County and the Rico-Argentine Mine located in Dolores County, Colorado. The following list of threatened, endangered, and candidate species should be helpful in your preparation of the environmental assessment for the project sites. These comments have been prepared under the provisions of the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 et. seq.).

The federally listed threatened and endangered species that could occur at or visit the proposed sites are:
(Weld County = W; Dolores County = D)

Birds:
- Bald eagle, *Haliaeetus leucocephalus*, Endangered (W,D)
- Whooping crane, *Grus americana*, Endangered (W)
- Least tern, *Sterna antillarium*, Endandered (W)
- Piping plover, *Charadrius melodus*, Threatened (W)
- Southwestern willow flycatcher, *Empidonax traillí extimus*, Proposed Endangered (D)
- Mexican spotted owl, *Strix occidentalis lucida*, Threatened (D)

Mammals:
- Black-footed ferret, *Mustela nigripes*, Endangered (W,D)

Plants:
- Ute ladies'-tresses orchid, *Spiranthes diluvialis*, Threatened (W)

The Service also is interested in the protection of species which are candidates for official listing as threatened or endangered (Federal Register, Vol. 56, No. 225, November 21, 1991; Vol. 55, No. 35, February 21, 1990). While these species presently have no legal protection under the ESA, it is within the spirit of this act to consider project impacts to potentially sensitive candidate species. It is the intention of the Service to protect these species before human-related activities adversely impact their habitat to a degree that they would need to be listed and,